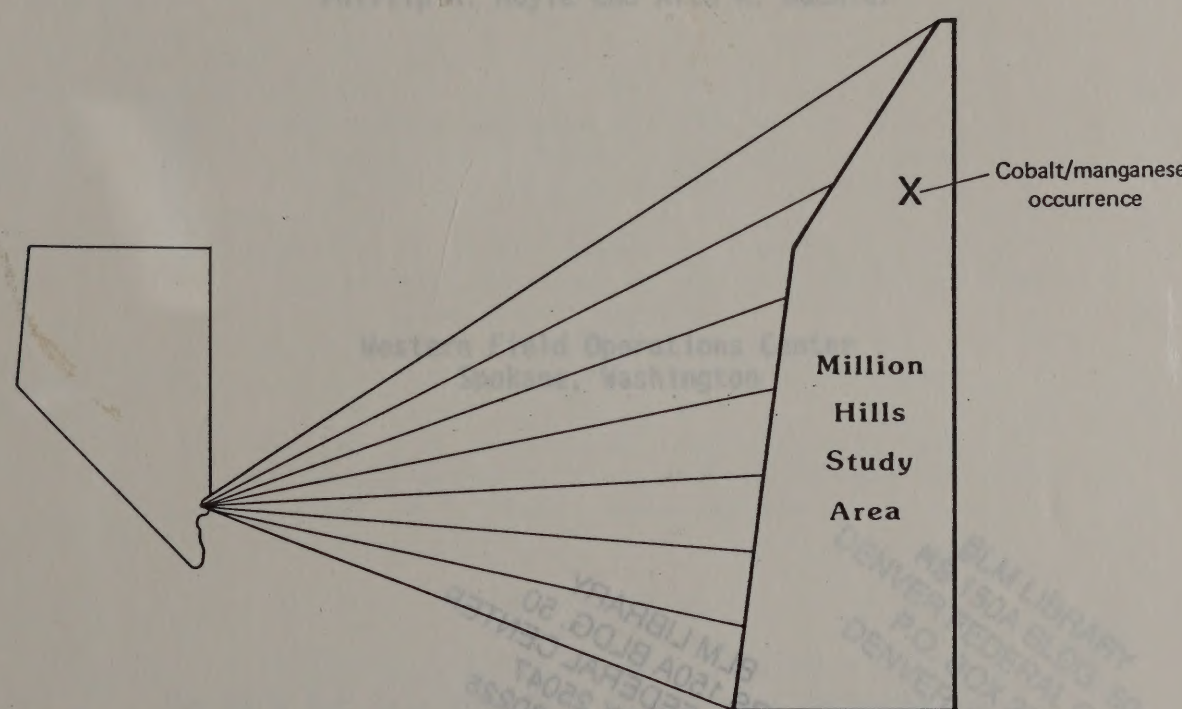
MLA 3-90

**Mineral Land Assessment/
Open File Report 1990**

Site-specific Investigation of a Cobalt/Manganese Occurrence in the Million Hills Study Area, Clark County, Nevada



BUREAU OF MINES

UNITED STATES DEPARTMENT OF THE INTERIOR

SITE-SPECIFIC INVESTIGATION OF A COBALT/MANGANESE OCCURRENCE IN THE MILLION HILLS STUDY AREA, CLARK COUNTY, NEVADA

By
Phillip R. Moyle and Alan R. Buehler

Western Field Operations Center
Spokane, Washington

UNITED STATES DEPARTMENT OF THE INTERIOR
Manuel Lujan, Jr., Secretary

BUREAU OF MINES
T S Ary, Director

PREFACE

The Wilderness Act (Public Law 88-577, September 3, 1964) and related acts require the U.S. Geological Survey and the U.S. Bureau of Mines to survey certain areas on Federal lands ". . . to determine the mineral values, if any, that may be present . . ." Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a Bureau of Mines site-specific investigation of an area in the Million Hills Wilderness Study Area, Clark County, Nevada.

The data for this open-file report were gathered and interpreted by Bureau of Mines personnel from Western Field Operations Center, East 360 Third Avenue, Spokane, WA 99202. The report has been edited by members of the Branch of Resource Evaluation at the field center and reviewed at the Division of Mineral Land Assessment, Washington, DC.

CONTENTS

ILLUSTRATIONS

CONTENTS--Continued

ILLUSTRATIONS--Continued

TABLES

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cps	count per second
ft	foot
mi	mile
mm	millimeter
ppb	part per billion
ppm	part per million
%	percent

CHEMICAL ABBREVIATIONS USED IN THIS REPORT

Ag	silver
Au	gold
Ba	barium
Co	cobalt
Cu	copper
H	hydrogen
Hg	mercury
Mn	manganese
Ni	nickel
O	oxygen
Pb	lead
Tl	thallium
Zn	zinc
HCl	hydrochloric acid
HF	hydrofluoric acid
HNO_3	nitric acid
H_2SO_4	sulfuric acid
MIBK	methyl isobutyl ketone

UNIT CONVERSIONS USED IN THIS REPORT

1 mm	= 0.039	in.
1 ppb	= 0.000029	oz/ton
1 ppm	= 0.029	oz/ton
1 ppm	= 0.0001	%
1 %	= 10,000	ppm

SUMMARY

A cobalt/manganese occurrence in Clark County, Nevada was the subject of a site-specific mineral investigation by the U.S. Bureau of Mines in 1988-90. The study site is in the northern part of the Million Hills (wilderness) study area which is administered by the Bureau of Land Management. Field work during a period of one week consisted of geological mapping and sampling of workings and outcrops, and geochemical and geophysical surveys conducted on four transects totalling 7,600 ft. Although the concentrations of cobalt (0.1 to 0.5 percent) detected in samples from the fissure zones are within the range of grades associated with world-class economic deposits, the volume of material enriched in cobalt at the study site is insufficient to warrant consideration as a potential resource. Concentrations of manganese, nickel, copper, lead, zinc, barium, and thallium, although anomalous, are too low for economic consideration.

At the study site, workings consist of three trenches and nine pits. The exploration history is unknown, and no production is reported.

The investigation centered on a north-trending, east-dipping system of narrow, mineralized fissures intermittently exposed for 400 ft along strike. Mineralization consists predominantly of aragonite, asbolane (cobaltian wad), pyrolusite, and psilomelane. Manganese oxides occur as distinct interlayers with aragonite and exhibit colloform texture. The fissures cut, and aragonite locally replaces, poorly sorted conglomerate which is underlain at shallow depth by carbonate rocks. Carbonate beds strike N. 17° to 35° E., dip 42° to 45° SE, and may be associated with the Permian Kaibab and/or Toroweap Formations. Basement rocks to the northwest and west of the study site are cut by the northeast-trending Gold Butte fault.

Eighteen rock samples were collected at the study site, and three samples were taken from an exposure of the Gold Butte fault. In addition to manganese, fissure zones at the study site were determined to be enriched in cobalt, copper, lead, zinc, barium, nickel, and thallium. Cobalt concentrations ranged from 1,030 to 4,935 ppm, and manganese concentrations ranged from 0.98 to 3.6 percent. Enrichment of most of the elements was probably due to adsorption by hydrous manganese oxides from circulating meteoric water in near-surface weathering conditions.

Forty-one soil samples were collected at 50- to 100-ft intervals from three transects surveyed across the fissure system; 23 additional samples were taken at 200-ft intervals from a 4,400-ft transect surveyed northwest of the study site. Analyses showed modest increases in cobalt, lead, and mercury over the fissure zone.

Radiometric, magnetic, and very low frequency (VLF) electromagnetic surveys over the transects exhibited a variety of responses. Electromagnetic surveys showed distinct inflections over the fissure zone and over an inferred projection of the Gold Butte fault. Magnetic intensity over the Gold Butte fault was low, suggesting demagnetization of country rock by hydrothermal solutions. Radiometric readings were generally low, ranging between 10 and 30 counts per second

INTRODUCTION

Purpose and Scope

The U.S. Bureau of Mines (USBM) conducts detailed site-specific investigations of areas determined by previous USBM and U.S. Geological Survey (USGS) investigations to have a high probability of containing mineral resources. Emphasis is on strategic and critical minerals at sites lacking sufficient information to interest industry, or on lands to which access by the private sector is restricted. Areas selected for site-specific study are on public lands and typically have had historic mining activity.

Site-specific studies are intended to identify possible exploration targets and estimate mineral endowment where adequate data are available. Investigations generally consist of detailed geologic mapping, geochemical sampling, geophysical surveys, and other appropriate methods which are employed to define targets suitable for further investigation. Excavation or drilling may be utilized in a subsequent phase to expose or otherwise confirm the presence and extent of a buried target. The results of site-specific investigations are made available to the public in USBM Mineral Land Assessment (MLA) open-file reports.

Location and Access

This USBM site-specific investigation involved a cobalt/manganese occurrence in the northern part of the 9,599-acre Million Hills study area, a portion of a Bureau of Land Management (BLM) administered Wilderness Study Area (WSA) in Clark County, NV (fig. 1). The occurrence is located approximately 33 mi south of Mesquite, NV, 6 mi north of Lake Mead, and one-half mile west of the Nevada/Arizona border.

Access from Mesquite to the area is gained by driving 7 mi west on Interstate 15 to the Riverside exit and traveling approximately 40 mi south on the paved and graded New Gold Butte Rd. and 7 mi east on 4-wheel-drive roads which lead through Garden Wash. Driving time to the site is nearly two hours.

Elevation at the study site is 2,500 ft. The surrounding terrain consists of a subparallel series of east-draining dry washes separated by 50- to 60-ft-high ridges composed of conglomerate underlain by

Radiometric, magnetic, and very low frequency (VLF) electromagnetic surveys over the transects exhibited a variety of responses. Electromagnetic surveys showed distinct inflections over the fissure zone and over an inferred projection of the Gold Butte fault. Magnetic intensity over the Gold Butte fault was low, suggesting demagnetization of country rock by hydrothermal solutions. Radiometric readings were generally low, ranging between 18 and 28 counts per second

INTRODUCTION

Purpose and Scope

The U.S. Bureau of Mines (USBM) conducts detailed site-specific investigations of areas determined by previous USBM and U.S. Geological Survey (USGS) investigations to have a high probability of containing mineral resources. Emphasis is on strategic and critical minerals at sites lacking sufficient information to interest industry, or on lands to which access by the private sector is restricted. Areas selected for site-specific study are on public lands and typically have had historic mining activity.

Site-specific studies are intended to identify possible exploration targets and estimate mineral endowment where adequate data are available. Investigations generally consist of detailed geologic mapping, geochemical sampling, geophysical surveys, and other appropriate methods which are employed to define targets suitable for further investigation. Excavation or drilling may be utilized in a subsequent phase to expose or otherwise confirm the presence and extent of a buried target. The results of site-specific investigations are made available to the public in USBM Mineral Land Assessment (MLA) open-file reports.

Location and Access

This USBM site-specific investigation involved a cobalt/manganese occurrence in the northern part of the 9,509-acre Million Hills study area, a portion of a Bureau of Land Management (BLM) administered Wilderness Study Area (WSA) in Clark County, NV (fig. 1). The occurrence is located approximately 33 mi south of Mesquite, NV, 6 mi north of Lake Mead, and one-half mile west of the Nevada/Arizona border.

Access from Mesquite to the area is gained by driving 7 mi west on Interstate 15 to the Riverside exit and traveling approximately 40 mi south on the paved and graded New Gold Butte Rd. and 7 mi east on 4-wheel-drive roads which lead through Kardem Wash. Driving time to the site is nearly two hours.

Elevation at the study site is 2,500 ft. The surrounding terrain consists of a subparallel series of east-draining dry washes separated by 50- to 60-ft-high ridges composed of conglomerate underlain by

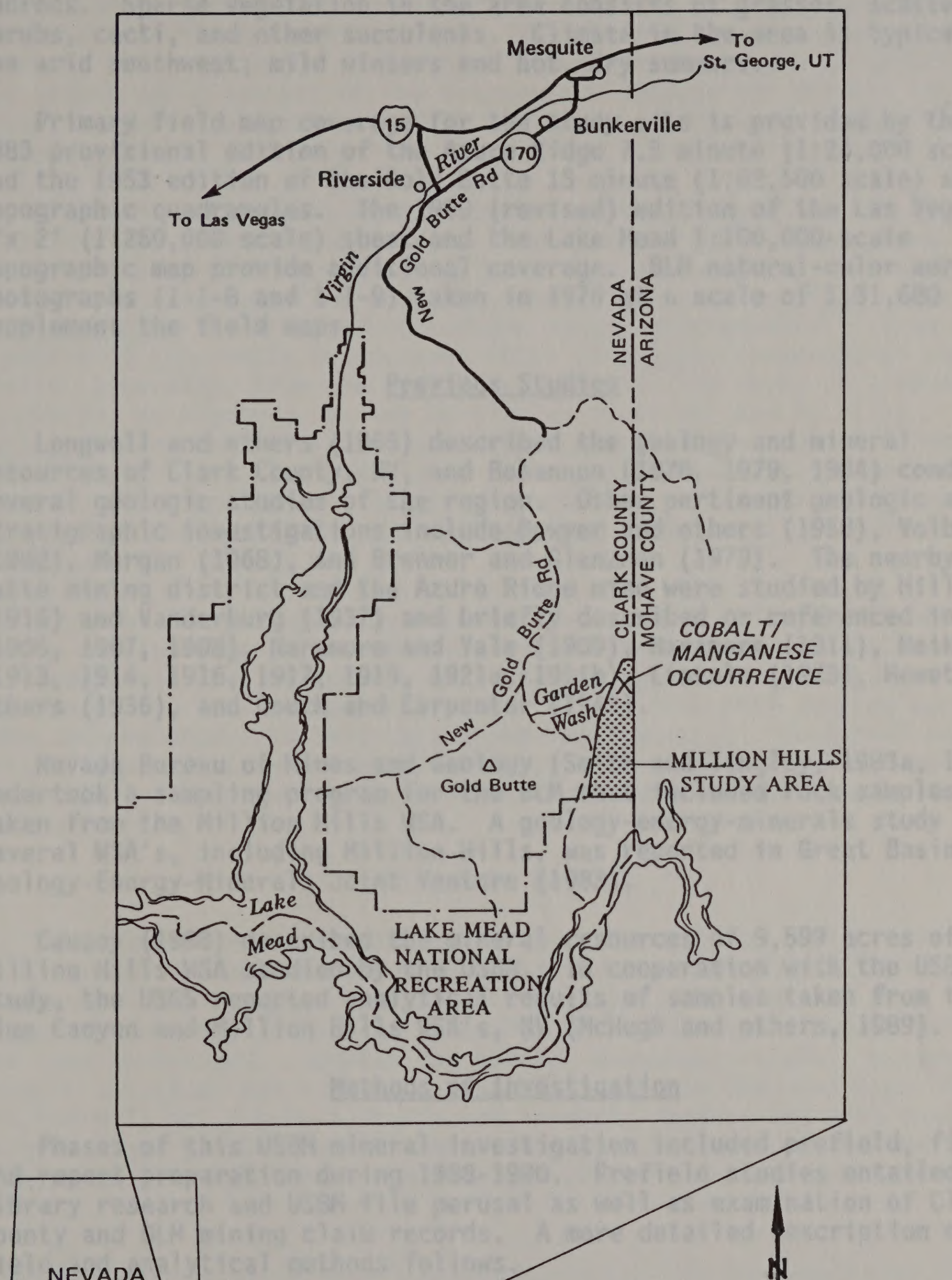


FIGURE 1.– Location of a cobalt/manganese occurrence in the Million Hills study area, Clark County, NV

bedrock. Sparse vegetation in the area consists of grasses, scattered shrubs, cacti, and other succulents. Climate in the area is typical of the arid southwest; mild winters and hot, dry summers.

Primary field map coverage for the study site is provided by the 1983 provisional edition of the Azure Ridge 7.5 minute (1:24,000 scale) and the 1953 edition of the Gold Butte 15 minute (1:62,500 scale) series topographic quadrangles. The 1969 (revised) edition of the Las Vegas 1°x 2° (1:250,000 scale) sheet and the Lake Mead 1:100,000-scale topographic map provide additional coverage. BLM natural-color aerial photographs (1-1-8 and 1-1-9) taken in 1976 at a scale of 1:31,680 supplement the field maps.

Previous Studies

Longwell and others (1965) described the geology and mineral resources of Clark County, NV, and Bohannon (1978, 1979, 1984) conducted several geologic studies of the region. Other pertinent geologic and stratigraphic investigations include Bowyer and others (1958), Volborth (1962), Morgan (1968), and Brenner and Glanzman (1979). The nearby Gold Butte mining district and the Azure Ridge mine were studied by Hill (1916) and Vanderburg (1937) and briefly described or referenced in Yale (1906, 1907, 1908), Naramore and Yale (1909), Naramore (1911), Heikes (1913, 1914, 1916, 1917, 1919, 1921a, 1921b), Lincoln (1923), Hewett and others (1936), and Couch and Carpenter (1943).

Nevada Bureau of Mines and Geology (Smith and Tingley, 1983a, 1983b) undertook a sampling program for the BLM that included rock samples taken from the Million Hills WSA. A geology-energy-minerals study of several WSA's, including Million Hills, was reported in Great Basin Geology-Energy-Minerals Joint Venture (1983).

Causey (1988) described the mineral resources of 9,599 acres of the Million Hills WSA studied by the USBM. In cooperation with the USBM study, the USGS reported analytical results of samples taken from the Lime Canyon and Million Hills WSA's, NV (McHugh and others, 1989).

Methods of Investigation

Phases of this USBM mineral investigation included prefield, field, and report preparation during 1988-1990. Prefield studies entailed library research and USBM file perusal as well as examination of Clark County and BLM mining claim records. A more detailed description of the field and analytical methods follows.

Field Methods

Field studies involved two phases of investigation. First, workings and rock outcrops at the site were examined, mapped, and sampled. Second, geochemical soil samples and geophysical data were collected at

bedrock. Sparse vegetation in the area consists of grasses, scattered shrubs, cacti, and other succulents. Climate in the area is typical of the arid southwest: mild winters and hot, dry summers.

Primary field map coverage for the study site is provided by the 1983 provisional edition of the Azure Ridge 7.5 minute (1:24,000 scale) and the 1953 edition of the Gold Butte 15 minute (1:62,500 scale) series topographic quadrangles. The 1969 (revised) edition of the Las Vegas 1°x 2° (1:250,000 scale) sheet and the Lake Mead 1:100,000-scale topographic map provide additional coverage. BLM natural-color aerial photographs (1-1-8 and 1-1-9) taken in 1978 at a scale of 1:31,680 supplement the field maps.

Previous Studies

Longwell and others (1965) described the geology and mineral resources of Clark County, NV, and Bohannon (1978, 1979, 1984) conducted several geologic studies of the region. Other pertinent geologic and stratigraphic investigations include Beever and others (1958); Volborth (1962), Morgan (1968), and Brenner and Glanzman (1979). The nearby Gold Butte mining district and the Azure Ridge mine were studied by Hill (1916) and Vanderburg (1937) and briefly described or referenced in Yale (1906, 1907, 1908), Baramore and Yale (1909), Baramore (1911), Heikes (1913, 1914, 1916, 1917, 1919, 1921a, 1921b), Lincoln (1923), Hewett and others (1936), and Couch and Carpenter (1943).

Nevada Bureau of Mines and Geology (Smith and Tingley, 1983a, 1983b) undertook a sampling program for the BLM that included rock samples taken from the Million Hills WSA. A geology-energy-minerals study of several WSA's, including Million Hills, was reported in Great Basin Geology-Energy-Minerals Joint Venture (1983).

Causey (1988) described the mineral resources of 8,599 acres of the Million Hills WSA studied by the USBM. In cooperation with the USBM study, the USGS reported analytical results of samples taken from the Lime Canyon and Million Hills WSA's, NV (McHugh and others, 1989).

Methods of Investigation

Phases of this USBM mineral investigation included prefield, field, and report preparation during 1989-1990. Prefield studies entailed library research and USBM file perusal as well as examination of Clark County and BLM mining claim records. A more detailed description of the field and analytical methods follows.

Field Methods

Field studies involved two phases of investigation. First, workings and rock outcrops at the site were examined, mapped, and sampled. Second, geochemical soil samples and geophysical data were collected at

50- to 200-ft-intervals along four transects[1] to identify possible extensions of the mineralized zone. The distribution of workings and outcrops and orientation of geologic structures were used to determine the length and placement of the transects. Geophysical surveys included magnetic, very low frequency (VLF) electromagnetic, and radiometric techniques.

Eighteen rock samples were collected at the study site, and three additional rock samples were taken from a nearby fault zone. Rock samples were of four types: 1) chip--a regular series of rock chips taken in a continuous line across a mineralized zone or other exposure; 2) random chip--a series of rock chips taken unsystematically from an exposure of apparently homogeneous rock; 3) select--fragments of rock chosen, generally, from the most highly mineralized rocks of a dump, stockpile, or exposure, or any particular fraction; and 4) drill cuttings--fragments of rock flushed from a drill hole and recovered from around the collar. Two additional rock specimens were submitted to Drs. James R. Snook and Russell Boggs, respectively, at Eastern Washington University, Cheney, WA for transmitted- and reflected-light petrographic analysis.

Although the geologic environment, for example arid climate and poorly developed soils, was not considered particularly favorable for soil sampling, this method was utilized to augment the geophysical data because of the lack of rock exposures. Sixty-four soil samples were taken at predetermined intervals along the transects. Each soil sample weighed approximately one pound and was taken, where possible, from immediately below the surface organic layer, presumably from the "B" horizon.

Analytical Methods

Rock samples were crushed, pulverized, homogenized, split, and sent to a commercial laboratory for analysis[2] (measurable limits listed with elements). Soil samples were dried and sieved; the minus-80-mesh fractions were then commercially analyzed for the same elements using the same techniques. Samples for cobalt, manganese, nickel, copper, barium, thallium, and zinc were digested in HF and HNO_3 and dissolved in 3 N (normal) HCl. Cobalt, manganese, nickel, copper, and zinc content were analyzed by flame atomic absorption spectroscopy, and barium was determined by inductively coupled argon-plasma emission spectrometry.

---

[1] Parallel surveyed sample lines.

[2] Cobalt (1 ppm), manganese (1 ppm), gold (0.1 ppb), silver (0.2 ppm), copper (1 ppm), lead (1 ppm), zinc (1 ppm), barium (10 ppm), mercury (10 ppb), nickel (1 ppm), and thallium (0.01 ppm).

50- to 200-ft-intervals along four transects[a] to identify possible extensions of the mineralized zone. The distribution of workings and outcrops and orientation of geologic structures were used to determine the length and placement of the transects. Geophysical surveys included magnetic, very low frequency (VLF) electromagnetic, and radiometric techniques.

Eighteen rock samples were collected at the study site, and three additional rock samples were taken from a nearby fault zone. Rock samples were of four types: 1) chip--a regular series of rock chips taken in a continuous line across a mineralized zone or other exposure; 2) random chip--a series of rock chips taken unsystematically from an exposure of apparently homogeneous rock; 3) select--fragments of rock chosen, generally, from the most highly mineralized rocks of a dump, stockpile, or exposure, or any particular fraction; and 4) drill cuttings--fragments of rock flushed from a drill hole and recovered from around the collar. Two additional rock specimens were submitted to Drs. James R. Snook and Russell Boggs, respectively, at Eastern Washington University, Cheney, WA for transmitted- and reflected-light petrographic analysis.

Although the geologic environment, for example arid climate and poorly developed soils, was not considered particularly favorable for soil sampling, this method was utilized to augment the geophysical data because of the lack of rock exposures. Sixty-four soil samples were taken at predetermined intervals along the transects. Each soil sample weighed approximately one pound and was taken, where possible, from immediately below the surface organic layer, presumably from the "B" horizon.

Analytical Methods

Rock samples were crushed, pulverized, homogenized, split, and sent to a commercial laboratory for analysis[b] (measurable limits listed with elements). Soil samples were dried and sieved; the minus-80-mesh fractions were then commercially analyzed for the same elements using the same techniques. Samples for cobalt, manganese, nickel, copper, barium, thallium, and zinc were digested in HF and HNO_3 and dissolved in 3 N (normal) HCl. Cobalt, manganese, nickel, copper, and zinc content were analyzed by flame atomic absorption spectroscopy, and barium was determined by inductively coupled argon-plasma emission spectrometry.

---

[a] Parallel surveyed sample lines.

[b] Cobalt (1 ppm), manganese (1 ppm), gold (0.1 ppb), silver (0.2 ppm), copper (1 ppm), lead (1 ppm), zinc (1 ppm), barium (10 ppm), mercury (10 ppb), nickel (1 ppm), and thallium (0.01 ppm).

Thallium was extracted with MIBK after HF-HNO_3 digestion and content was determined by electrothermal atomic absorption spectroscopy. Gold content was analyzed by electrothermal atomic absorption spectroscopy after digestion in aqua regia (HCl-HNO_3) and extraction with MIBK. Silver and lead content were determined by use of a flame absorption spectrophotometer equipped with a background detector after digestion in aqua regia with dissolution in 2 N HCl. Mercury was determined by cold-vapor hydride generation atomic absorption after digestion in H_2SO_4 and HNO_3. Accuracy of analysis was checked by preparation and analysis of reference standards.

Rock and soil analyses are listed in appendices A and B, respectively. Geophysical data are listed in appendix C, and petrographic descriptions are in appendix D.

Acknowledgements

The authors extend special thanks to Douglas Causey, Physical Scientist at WFOC (Western Field Operations Center), for proposing this site-specific investigation. Ronald Stotelmeyer, Supervisory Physical Scientist at WFOC, ably assisted in the field.

GEOLOGIC SETTING

The study site is in the Basin and Range physiographic province. Geology of the area has been studied and described by various authors, most notably Longwell and others (1965) and Bohannon (1978). The following descriptions are based primarily on their work and from observations of the authors.

Several rock types are exposed in the area (fig. 2). At the study site a thin veneer of conglomerate covers most of the surface and unconformably overlies Paleozoic sedimentary rocks, primarily thin-bedded carbonates. Permian sedimentary rocks, exposed in three outcrops at the study site (pl. 1), consist of tan, gray and black, microcrystalline, fossiliferous limestone. Beds strike N. 17° to 35° E. and dip 42° to 45° SE (pl. 1 and appendix A, nos. 9 and 10). These rock outcrops are on the projected strike of lithologically and structurally similar rocks of the Permian Kaibab and Toroweap Formations which are well exposed in the Million Hills about one mile south (fig. 2). These Paleozoic rocks overlie Precambrian granitic and metamorphic rocks. Both Precambrian and Paleozoic rocks host mineral deposits in the south part of the Gold Butte mining district eight miles southwest (Longwell and others, 1965, pl. 12). Nearby outcrops of the Tertiary Horse Spring Formation, as well as those of the Muddy Creek Formation and other younger volcanic rocks, are shown on figure 2 as undifferentiated sedimentary and volcanic rocks.

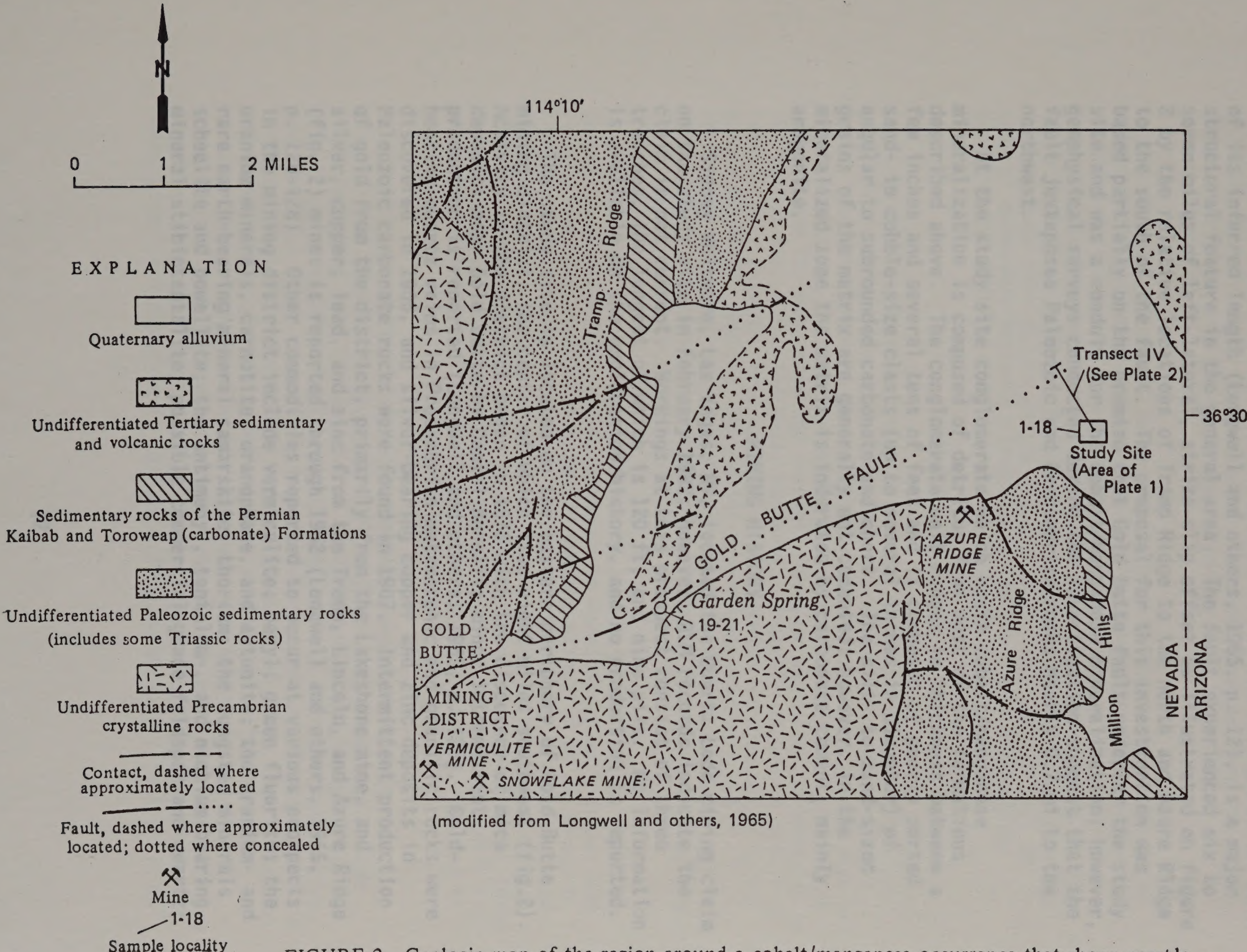


FIGURE 2.–Geologic map of the region around a cobalt/manganese occurrence that shows sample localities at the study site and on Gold Butte fault

The Gold Butte fault, which trends N. 70° E. and is covered for most of its inferred length (Longwell and others, 1965, p. 12), is a major structural feature in the general area. The fault experienced six to seven miles of left-lateral, strike-slip offset as illustrated on figure 2 by the relative locations of Tramp Ridge to the north and Azure Ridge to the south of the fault. The proposal for this investigation was based partially on the premise that Gold Butte fault underlay the study site and was a conduit for the cobalt/manganese mineralization; however, geophysical surveys conducted during the investigation suggest that the fault juxtaposes Paleozoic and Precambrian rocks nearly 0.7 mi to the northwest.

At the study site conglomerate which hosts cobalt/manganese mineralization is composed of detritus from most of the formations described above. The conglomerate unit ranges in thickness between a few inches and several tens of feet and is composed of poorly sorted sand- to cobble-size clasts (up to several inches in diameter) of angular to subrounded carbonate and chert. The silt- to sand-sized grains of the matrix are generally not cemented; however, in the mineralized zone the matrix is indurated by carbonate cement, mainly aragonite.

MINING HISTORY

Sidney Whitmore, Las Vegas, NV, located the Quartz Lode mining claim on the study site in February 1982; however, BLM records indicate the claim is not current. Workings at this prospect consist of three trenches, the longest of which is 120 ft, and nine pits. No information is available on the exploration history, and no production is reported.

The study site is located on the eastern periphery of Gold Butte mining district, the center of which lies eight miles southwest (fig.2). Activity in the district began in 1873 with the discovery of mica deposits near Gold Butte by Daniel Bonelli; minor intermittent production is reported (Longwell and others, 1965, p. 126). Gold-bearing quartz veins in Precambrian metamorphic and granitic rocks were discovered in 1905, and silver-bearing copper and zinc deposits in Paleozoic carbonate rocks were found in 1907. Intermittent production of gold from the district, primarily from the Lakeshore mine, and silver, copper, lead, and zinc from the Tramp, Lincoln, and Azure Ridge (fig. 2) mines is reported through 1962 (Longwell and others, 1965, p. 126-128). Other commodities reported to occur at various prospects in the mining district include vermiculite; beryl; green fluorite; the uranium minerals, carnotite, uranophane, and autunite; the uranium- and rare earth-bearing mineral samarskite; thorium; the tungsten minerals scheelite and powellite; the antimony-, tantalum-, and niobium-bearing mineral stibiotantalite; possible commercial-grade feldspar and quartz;

The Gold Butte fault, which trends N. 70° E. and is covered for most of its inferred length (Longwell and others, 1965, p. 12), is a major structural feature in the general area. The fault experienced six to seven miles of left-lateral, strike-slip offset as illustrated on figure 2 by the relative locations of Tramp Ridge to the north and Azure Ridge to the south of the fault. The proposal for this investigation was based partially on the premise that Gold Butte fault underlay the study site and was a conduit for the cobalt/manganese mineralization; however, geophysical surveys conducted during the investigation suggest that the fault juxtaposes Paleozoic and Precambrian rocks nearly 0.7 mi to the northwest.

At the study site conglomerate which hosts cobalt/manganese mineralization is composed of detritus from most of the formations described above. The conglomerate unit ranges in thickness between a few inches and several tens of feet and is composed of poorly sorted sand- to cobble-size clasts (up to several inches in diameter) of angular to subrounded carbonate and chert. The silt- to sand-sized grains of the matrix are generally not cemented; however, in the mineralized zone the matrix is indurated by carbonate cement, mainly aragonite.

MINING HISTORY

Sidney Whitmore, Las Vegas, NV, located the Quartz Lode mining claim on the study site in February 1982; however, BLM records indicate the claim is not current. Workings at this prospect consist of three trenches, the longest of which is 120 ft, and nine pits. No information is available on the exploration history, and no production is reported.

The study site is located on the eastern periphery of Gold Butte mining district, the center of which lies eight miles southwest (Fig.2). Activity in the district began in 1873 with the discovery of mica deposits near Gold Butte by Daniel Bonelli; minor intermittent production is reported (Longwell and others, 1965, p. 126). Gold-bearing quartz veins in Precambrian metamorphic and granitic rocks were discovered in 1908, and silver-bearing copper and zinc deposits in Paleozoic carbonate rocks were found in 1907. Intermittent production of gold from the district, primarily from the Lakeshore mine, and silver, copper, lead, and zinc from the Tramp, Lincoln, and Azure Ridge (Fig. 2) mines is reported through 1962 (Longwell and others, 1965, p. 126-128). Other commodities reported to occur at various prospects in the mining district include vermiculite; beryl; green fluorite; the uranium minerals, carnotite, uranophane, and autunite; the uranium- and rare earth-bearing mineral samarskite; thorium; the tungsten minerals scheelite and powellite; the antimony-, tantalum-, and niobium-bearing mineral stibiotantalite; possible commercial-grade feldspar and quartz;

and magnesite (Pampeyan and Bowyer, 1965). In addition, germanium and gallium concentrations were detected in select samples from the Azure Ridge mine (data on file at Bureau of Mines, WFOC, East 360 Third Avenue, Spokane, WA. 99202).

No deposits of cobalt or manganese are reported in the Gold Butte district. The nearest reported cobalt is associated with nickel and platinum enrichment at the Key West and Great Eastern mines in Precambrian gneisses of the Virgin Mountains about 17 mi north of the study site (Beal, 1964). Manganese is reported 20 mi to the southwest of the study site at the Virgin River deposit, the eastern most of several manganese deposits clustered around the Three Kids mining district (Schilling, 1962).

COMMODITY HIGHLIGHTS

Cobalt and manganese are both considered to be "strategic and critical materials" as defined by the Federal Emergency Management Agency and are important for their special properties in the defense and steel industries. Estimated import reliance in 1989 for cobalt was 86 percent and for manganese 100 percent. Neither commodity is produced in the United States for the major end uses. However, secondary cobalt is domestically recycled from superalloy or cemented carbide scrap (U.S. Bureau of Mines, 1990, p. 48 and 106), and minor sporadic U.S. production of manganese, at low grades ranging from 5 to 35 percent manganese, is utilized as a brick pigment and in the production of pig iron (Jacoby, 1983, p. 901).

The highest known concentrations of cobalt in the earth's crust are in mafic and ultramafic rocks, commonly in association with copper and nickel. Current world production is derived primarily as a coproduct from stratabound copper deposits in Zaire and Zambia. Grades of these deposits range from 0.1 to 2 percent cobalt. Domestic mine production of cobalt ceased in 1971. The Blackbird district of Lemhi County, Idaho was the largest profitable cobalt mining district in the U.S. until the mine closed in 1959. The cobalt grade at the Blackbird is reported to be 0.6 percent (Kirk, 1985, p. 173-174).

The minimum grade for typical economic manganese deposits is generally 25 percent; most contain 25 to 40 percent manganese. High-grade manganese ores (35 percent or greater) processed in the U.S., primarily for metallurgical applications, are all derived from foreign sources. The major commercial sources are sedimentary deposits, and the largest producers are the USSR and the Republic of South Africa (Harben and Bates, 1984, p. 286). Jones (1985, p. 486) notes "At current prices, there are no reserves of manganese ore in the United States containing 35 % or more manganese or from which concentrates of such ore could be commercially produced... The average grade of manganese in these (domestic) deposits is less than 20 %, generally less than 10 %."

and magnesite (Pansze and Bowyer, 1985). In addition, germanium and gallium concentrations were detected in select samples from the Azure Ridge mine (data on file at Bureau of Mines, WFOC, East 360 Third Avenue, Spokane, WA 99202).

No deposits of cobalt or manganese are reported in the Gold Butte district. The nearest reported cobalt is associated with nickel and platinum enrichment at the Key West and Great Eastern mines in Precambrian gneisses of the Virgin Mountains about 17 mi north of the study site (Beal, 1964). Manganese is reported 20 mi to the southwest of the study site at the Virgin River deposit, the eastern most of several manganese deposits clustered around the Three Kids mining district (Schilling, 1962).

COMMODITY HIGHLIGHTS

Cobalt and manganese are both considered to be "strategic and critical materials" as defined by the Federal Emergency Management Agency and are important for their special properties in the defense and steel industries. Estimated import reliance in 1989 for cobalt was 86 percent and for manganese 100 percent. Neither commodity is produced in the United States for the major end uses. However, secondary cobalt is domestically recycled from superalloy or cemented carbide scrap (U.S. Bureau of Mines, 1990, p. 48 and 105), and minor sporadic U.S. production of manganese, at low grades ranging from 5 to 35 percent manganese, is utilized as a brick pigment and in the production of pig iron (Jacoby, 1985, p. 501).

The highest known concentrations of cobalt in the earth's crust are in mafic and ultramafic rocks, commonly in association with copper and nickel. Current world production is derived primarily as a coproducts from stratabound copper deposits in Zaire and Zambia. Grades of these deposits range from 0.1 to 1 percent cobalt. Domestic mine production of cobalt ceased in 1971. The Blackbird district of Lemhi County, Idaho was the largest profitable cobalt mining district in the U.S. until the mine closed in 1959. The cobalt grade at the Blackbird is reported to be 0.6 percent (Kirk, 1985, p. 175-176).

The minimum grade for typical economic manganese deposits is generally 25 percent; most contain 25 to 60 percent manganese. High-grade manganese ores (35 percent or greater) processed in the U.S., primarily for metallurgical applications, are all derived from foreign sources. The major commercial sources are sedimentary deposits, and the largest producers are the USSR and the Republic of South Africa (Harben and Bates, 1984, p. 296). Jones (1985, p. 486) notes "At current prices, there are no reserves of manganese ore in the United States containing 35 % or more manganese or from which concentrates of such ore could be commercially produced... The average grade of manganese in these (domestic) deposits is less than 20 %, generally less than 10 %."

PRESENT INVESTIGATION

Description of Occurrence

Three trenches and nine pits at the study site (pl. 1 and fig. 3) expose a north-trending network of fissures partially to completely filled with aragonite, calcite, and cobalt-bearing manganese oxides. Fissures generally dip steeply, up to 75° to the east, range in thickness between a few inches and six feet, and cut partially indurated conglomerate. The mineral occurrence is intermittently exposed for approximately 400 ft along strike from the float at sample site no. 1 to the south end of the trench at sample site no. 18 (pl. 1); the subparallel fissures are up to 50 ft apart on the surface. Figure 4 illustrates the typical appearance of fissure-filling aragonite and encrusted manganese oxides exposed in the workface of a trench at sample nos. 2 to 5 (pl. 1). Atypical of the study site is the shallow westward dip of the partially aragonite-filled fissure exposed in this trench, which possibly follows a bedding plane in the conglomerate. A pit at sample site no. 7 is on an open fissure determined to be at least 20 ft deep. The walls of the fissure are encrusted with black manganese oxide.

Detailed transmitted- and reflected-light petrographic analyses of two select rock specimens are contained in appendix D. At least three different manganese minerals are present: 1) asbolane[3/], a hydrous manganese oxide containing cobalt oxide; 2) pyrolusite, a manganese oxide and the principal ore of manganese; and 3) psilomelane, a hydrous manganese oxide of variable composition commonly containing barium. Figure D-1, a photograph of the select rock specimens, shows manganese encrustations on comb-structured aragonite in carbonate-cemented conglomerate. Fissures are predominantly aragonite-filled with manganese oxides occurring as distinct interlayers with colloform texture, as random fragments, and as individual rounded colloform masses. Aragonite has replaced grains of country rock as well as manganese oxides.

Rock Sampling

Sixteen rock samples were collected from exposured fissure zones and from mineralized float at the study site (pl. 1, nos. 1-8 and 11-18). To provide a comparative background geochemical signature, two samples were taken of country rock at the site (pl. 1, nos. 9 and 10) and three

---

[3/] Cobaltian wad, also known as asbolite, earthy cobalt, or black cobalt; wad is a mixture of hydrous manganese oxides and other oxides, in this case primarily (up to 40 percent) an oxide of cobalt (CoO) (Palache and others, 1944, p. 566 to 571).

FIGURE 3.--Oblique aerial view west of workings at a cobalt/manganese occurrence

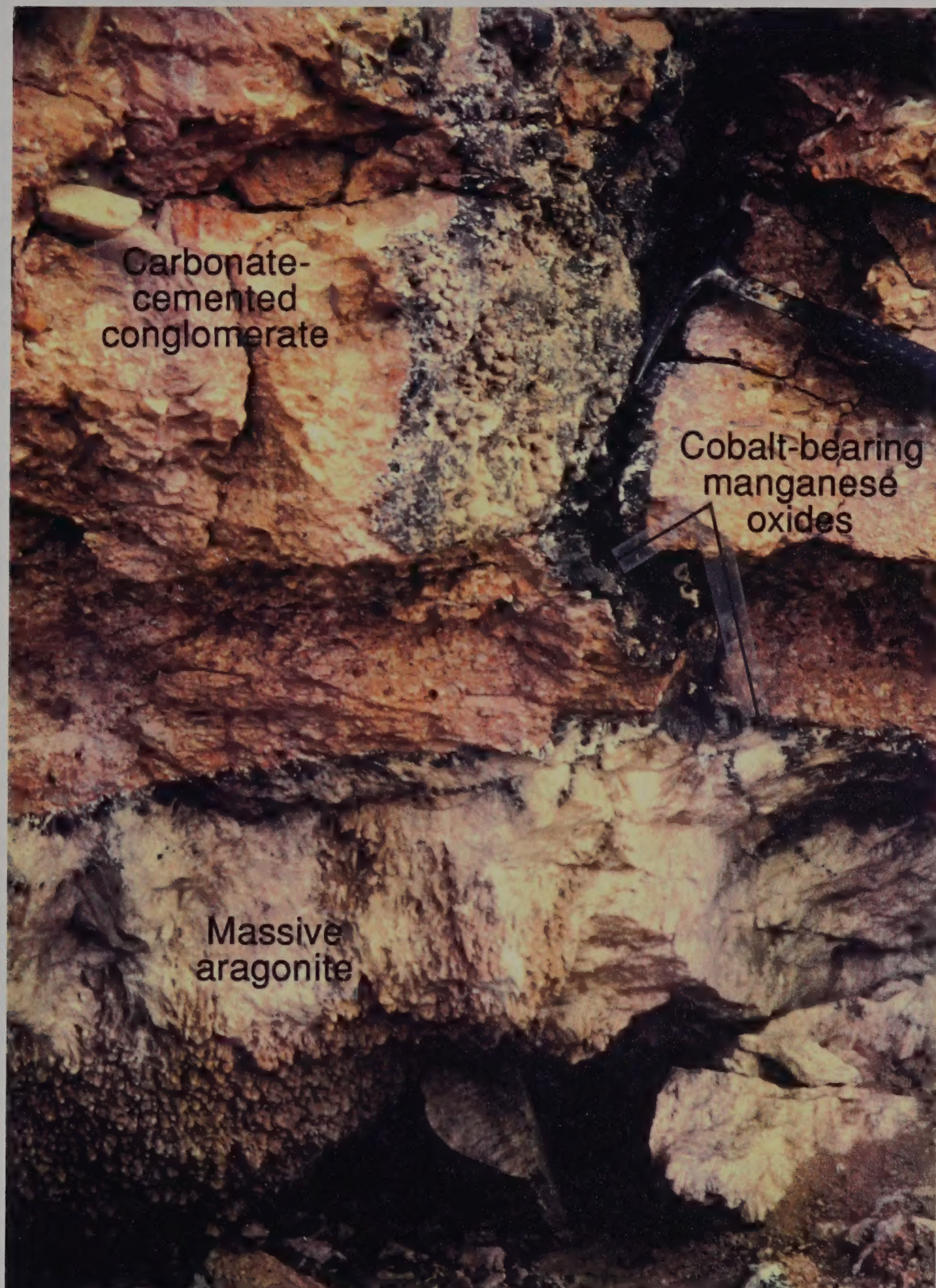


FIGURE 4.--Massive aragonite and cobalt-bearing manganese encrustations in fissures viewed in pit at sample locality nos. 2-5

additional samples were taken from exposured rock along the Gold Butte fault about five miles west of the study site (fig. 2, nos. 19-21). Sample descriptions and chemical analyses of the rock samples are listed in appendix A.

Twelve (pl. 1, nos. 1, 4, 7, 8, and 11-18) of the 16 mineralized samples contained concentrations of cobalt and manganese, as well as copper, lead, zinc, barium, nickel, and thallium, significantly elevated above the country rock samples taken from the site and those taken from Gold Butte fault. Ranges and average concentrations for these 12 samples are listed in table 1. For comparison, the average crustal abundance for these elements in carbonate rocks are shown in parentheses. All of the reported ranges and averages for these elements in the 12 rock samples from the study site significantly exceed average crustal abundance for the rock type present.

Concentrations of gold, silver, and mercury are generally at or below those typical of carbonate rocks in the earth's crust (Levinson, 1980, p. 43-44). Analyses of samples from the Gold Butte fault (fig. 2 and appendix A, nos. 19-21) do not show a significant correlation with samples from the study site.

Geochemical Soil Surveys

Forty-one soil samples were collected at 50- to 100-ft intervals from three west to east transects oriented perpendicular to the presumed trend of the fissure zone (pl. 1, transects I, II, and III). Transects I and II were surveyed over known exposures; transect III was surveyed north of the occurrence to determine if any extensions of the mineralized zone could be detected. Twenty-three additional soil samples were collected at 200-ft intervals from a 4,400-ft-long transect trending N. 35° W. from the center of the cobalt/manganese occurrence to a small outcrop of Precambrian (?) crystalline rocks (pl. 1 and fig. 2, transect IV) to determine if the Gold Butte fault could be identified. Chemical analyses of the soil samples are listed in appendix B, and geochemical profiles and geologic cross-sections of transects I-IV are shown on plate 2.

Although several element profiles fluctuated, only cobalt, lead, thallium, and possibly mercury, showed distinct increases over known exposures of the fissure zone. Manganese concentrations fluctuated radically, but no clear fissure zone signature was evidenced. Dispersion of elements in the soil may be a factor. None of the geochemical profiles over transect III showed a correlation to the projected location of the mineralized zone. Geochemical profiles of transect IV show coincidental increases in concentrations of manganese, zinc, nickel, copper, cobalt, and barium at the 2,000-ft station. The

Table 1.--Ranges and average concentrations of selected elements in 12 rock samples from a cobalt/manganese occurrence in the Million Hills study area, Clark County, Nevada

		Element Concentrations			
		12 samples, Co/Mn study site			Average for
Element	Units	Low	High	Average	Carbonates[1]
Cobalt	ppm	1030	4935	2385	4
Manganese	%	0.98	3.6	2.2	0.11
Copper	ppm	94	343	185	15
Lead	ppm	225	1250	775	8
Zinc	ppm	304	2095	999	25
Barium	ppm	512	3100	1566	100
Nickel	ppm	190	1280	560	12
Thallium	ppm	2	12	6.1	0.45[2]

[1] Levinson, 1980, p. 43-44.
[2] Average for earth's crust.

concentrations of thallium and mercury, apparently correlated with mineralization at the study site, do not show a corresponding behavior. Enrichment of these elements at the 2,000-ft station may be due to elevated (placer) concentrations in the colluvium rather than a mineralized zone in the underlying bed rock.

Geophysical Surveys

Radiometric, magnetic, and VLF electromagnetic geophysical surveys were conducted over the same transects utilized for the geochemical soil surveys (pl. 1 and fig. 2, transects I-IV). Instruments[4] used included: 1) a GR-101A gamma ray scintillometer with a resolution of ± 1 cps; 2) a G-836 portable proton magnetometer with a resolution of ± 10 gammas; and 3) an EM-16 VLF receiver with a resolution of ± 1 percent. Data are listed in appendix C, and geophysical profiles and geologic cross-sections are shown on plate 2.

Radiometric readings were low, ranging from 10 to 30 cps. Over the fissure zones of transects I and II (pl. 2) readings generally ranged from 10 to 15 cps, whereas readings commonly increased at the extreme ends of the transects. Transect III shows spurious results, irregular and low to the west and high to the east.

Total magnetic intensity profiles over transects I-III show no distinct pattern or signature over the occurrence; however, clear inflection points are observed in each of the electromagnetic profiles I-III. The presence of a conductive body may be indicated; however, the VLF electromagnetic method is very sensitive to faults and rock contacts. The profile inflections may only represent the presence of the fissure (fault?) zone. It is noteworthy that transect III shows a clear crossover which suggests continuation of the controlling structure north of the identified exposures.

A distinct magnetic response in the form of a low is shown at the 3,800-ft station of transect IV. This corresponds to a complex but pronounced crossover of the electromagnetic in-phase and quadrature profiles at the same location. The coincidence of the geophysical response with the nearby (600 ft or less) outcropping of crystalline rocks suggests a fault contact zone such as the Gold Butte fault. The low magnetic response is probably due to demagnetization of the country rock by hydrothermal solutions, a common phenomenon.

---

[4] Product names or references are for information purposes only and do not constitute an endorsement by the U.S. Bureau of Mines

APPRAISAL

Discussion

The manganese minerals present typically precipitate at atmospheric temperatures under oxidizing conditions, and the textures and presence of aragonite suggest a relatively low temperature of deposition. Interlayering of manganese oxides and aragonite, comb structures, and colloform textures observed in petrographic analyses indicate open-space deposition of manganese either from solution or a colloidal suspension. Cobalt detected in rock and soil samples is evidently contained in the mineral asbolane (cobaltian wad).

The selective enrichment of several elements in the fissure system, especially cobalt, nickel, and copper, is suggestive of a mafic or ultramafic source; however, none is in evidence near the study site. Alternatively, Levinson (1980, p. 134-136) describes a mechanism which selectively concentrates soluble metals by adsorption in near-surface weathering conditions which are generally oxidizing. According to Levinson, adsorption of metals, especially cobalt, nickel, and copper, by hydrous oxides of iron and/or manganese is a common phenomenon where drainage is restricted and alternating wet and dry weathering conditions exist.

The origin and full extent of the fissure system along which most of the mineralization is concentrated is unknown. Evidence suggests the subparallel fissures extend for at least 400 to 500 ft along strike and that they are spread laterally over about 50 ft. Observed mineralization is confined to the fissures which, in turn, are nearly on strike with bedding of the underlying Paleozoic carbonate rocks suggesting that circulating waters may have followed the bedding planes and exited at a break in slope. There is no evidence to demonstrate metallic enrichment at depth.

Conclusion

Cobalt and related metals enriched at the study site probably precipitated at or near the surface from circulating meteoric waters which contained significantly lower concentrations of the elements. Contributing conditions include an alternating wet and dry oxidizing environment, near-surface drainage limited or controlled by shallow bed rock and a localized fissure system, and concentrations of hydrous manganese oxides. The concentrations of cobalt (0.1 to 0.5 percent) detected in rock samples from the fissure zones are within the range of grades associated with world-class economic deposits; however, the observed volume at the study site is too small to be considered a potential resource. Because the source of cobalt concentrated in the fissure zones has not been determined, further investigations, such as geochemical sampling and analysis of well and spring water in the general area, are warranted. Concentrations of the other elements present, although anomalous, are insufficient to warrant consideration as a potential resource.

REFERENCES CITED

Beal, L. H., 1964, Cobalt-nickel-platinum occurrences in Nevada: Nevada Bureau of Mines Map 21, scale 1:1,000,000.

Bohannon, R. G., compiler, 1978, Preliminary geologic map of Las Vegas 1° x 2° quadrangle, Nevada, Arizona, and California: U.S. Geological Survey Open-File Report 78-670, 6 p., scale 1:250,000.

______, 1979, Strike-slip faults of the Lake Mead region of southern Nevada, in Armentrout, J. M., Cole, M. R., and TreBest, Harry, Jr., eds., Cenozoic paleogeography of the western United States: Los Angeles, California, Pacific Coast Paleogeography Symposium 3, Pacific Section, Society of Economic Paleontologists and Mineralogists, p. 129-139.

______, 1984, Nonmarine sedimentary rocks of Tertiary age in the Lake Mead region, southeastern Nevada and northwestern Arizona: U.S. Geological Survey Professional Paper 1259, 72 p.

Bowyer, Ben, Pampeyan, E. H., and Longwell, C. R., 1958, Geologic map of Clark County, Nevada: U.S. Geological Survey Map MF-138, scale 1:200,000.

Brenner, E. F., and Glanzman, R. K., 1979, Tertiary sediments in the Lake Mead area, Nevada, in Newman, G. W., and Goode, H. D., eds, Basin and Range Symposium and Great Basin Field Conference: Denver, Colorado, Rocky Mountain Association of Geologists, p. 313-323.

Causey, J. D., 1988, Mineral resources of the Million Hills study area, Clark County, Nevada: U.S. Bureau of Mines MLA Open-File Report 34-88, 29 p.

Couch, B. F., and Carpenter, J. A., 1943, Nevada's metal and mineral production (1859 - 1940, inclusive): University of Nevada Bulletin, v. XXXVII, no. 4, 159 p.

Great Basin GEM Joint Venture, 1983, Lake Mead G-E-M resources area (GRA No. NV-35) technical report (WSA's NV 050-0231, 050-0233, 050-0235, 050-0236, and 050-0238): prepared for the Bureau of Land Management, Contract YA-553-RFP2-1054, 49 p.

Harben, P. W., and Bates, R. L., 1984, Geology of the nonmetallics: New York, NY, Metal Bulletin Inc., 392 p.

Heikes, V. C., 1913, Nevada, in Mineral resources of the United States, calendar year 1912, and part I-metals: U.S. Geological Survey, p. 773-818.

Heikes, V. C., 1914, Gold, silver, copper, lead, and zinc in Nevada in 1913, in Mineral resources of the United States, calendar year 1913, part I-metals: U.S. Geological Survey, p. 803-844.

_____, 1916, Gold, silver, copper, lead, and zinc in Nevada in 1914, in Mineral resources of the United States, calendar year 1914, part I-metals: U.S. Geological Survey, p. 655-716.

_____, 1917, Gold, silver, copper, lead, and zinc in Nevada, in Mineral resources of the United States, 1915, part I-metals: U.S. Geological Survey, p. 613-654.

_____, 1919, Gold, silver, copper, lead, and zinc in Nevada, in Mineral resources of the United States, 1916, part I-metals: U.S. Geological Survey, p. 457-500.

_____, 1921a, Gold, silver, copper, lead, and zinc in Nevada, in Mineral resources of the United States, 1917, part I-metals: U.S. Geological Survey, p. 253-298.

_____, 1921b, Gold, silver, copper, lead, and zinc in Nevada, in Mineral resources of the United States, 1918, part I-metals: U.S. Geological Survey, p. 217-264.

Hewett, D. F., Callaghan, Eugene, Moore, B. N., Nolan, T. B., Rubey, W. W., and Schaller, W. T., 1936, Mineral resources of the region around Boulder Dam: U.S. Geological Survey Bulletin 871, 197 p.

Hill, J. M., 1916, Notes on some mining districts in eastern Nevada: U.S. Geological Survey Bulletin 648, 214 p.

Jacoby, C. H., 1983, Manganese, in LeFond, S. J., editor, Industrial minerals and rocks (nonmetallics other than fuels), 5th ed., Volume 2: New York, NY, Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., p. 897-908.

Jones, T. S., 1985, Manganese, in Mineral facts and problems, 1985 edition: U.S. Bureau of Mines Bulletin 675, p. 483-498.

Kirk, W. S., 1985, Cobalt, in Mineral facts and problems, 1985 edition: U.S. Bureau of Mines Bulletin 675, p. 171-183.

Levinson, A. A., 1980, Introduction to exploration geochemistry, 2nd ed.: Calgary, Alberta, Canada, Applied Publishing, 924 p.

Lincoln, F. C., 1923, Mining districts and mineral resources of Nevada: Nevada Newsletter Publishing Company, Reno, Nevada, 295 p.

Longwell, C. R., Pampeyan, E. H., Bowyer, Ben, and Roberts, R. J., 1965, Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines Bulletin 62, 218 p.

McHugh, J. B., Bullock, Jr., J. H., Roemer, T. A., Briggs, P. H., and Nowlan, G. A., 1989, Analytical results and sample locality map for stream-sediment and panned-concentrate samples from Lime Canyon and Million Hills Wilderness Study Areas, Clark County, Nevada: U. S. Geological Survey Open-File Report 89-25, 21 p.

Morgan, J. R., 1968, Structure and stratigraphy of the northern part of the South Virgin Mountains, Clark County, Nevada: M.S. thesis, University of New Mexico, Albuquerque, New Mexico, 102 p.

Naramore, Chester, 1911, Nevada, in Mineral resources of the United States, calendar year 1909, part I-metals: U.S. Geological Survey, p. 386-430.

Naramore, Chester, and Yale, C. G., 1909, Nevada, in Mineral resources of the United States, calendar year 1908, part I-metallic products: U.S. Geological Survey, p. 462-506.

Palache, Charles, Berman, Harry, and Frondel, Clifford, 1944, The system of mineralology, seventh edition, volume I: John Wiley and Sons, Inc., New York, 834 p.

Pampeyan, E. H., and Bowyer, Ben, 1965, Mineral resources map of Clark County, Nevada, in Longwell, C. R., Pampeyan, E. H., Bowyer, Ben, and Roberts, R. J., Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines Bulletin 62, Plate 1, scale 1:250,000.

Schilling, J. H., 1962, Manganese deposits in Nevada: Nevada Bureau of Mines Map 9, scale 1:1,000,000.

Smith, P. L., and Tingley, J. V., 1983a, A mineral inventory of the Esmeralda-Stateline Resource Area, Las Vegas District, Nevada: Nevada Bureau of Mines and Geology Open-File Report 83-11, 176 p.

_______, 1983b, Results of geochemical sampling within Esmeralda-Stateline Resource Area, Esmeralda, Clark, and southern Nye Counties, Nevada (portions of Death Valley, Goldfield, Kingman, Las Vegas, Mariposa and Tonopah 2° sheets): Nevada Bureau of Mines and Geology Open-File Report 83-12, 176 p.

U.S. Bureau of Mines, 1990, Mineral Commodity Summaries: 199 p.

Vanderburg, W. O., 1937, Reconnaissance of mining districts in Clark County, Nevada: U.S. Bureau of Mines Information Circular 6964, 81 p.

Longwell, C. R., Pampeyan, E. H., Bowyer, Ben, and Roberts, R. J., 1965, Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines Bulletin 62, 218 p.

McHugh, J. B., Bullock, Jr., J. H., Roemer, T. A., Briggs, P. H., and Horton, H. A., 1988, Analytical results and sample locality map for stream-sediment and panned-concentrate samples from Lime Canyon and Million Hills Wilderness Study Areas, Clark County, Nevada: U. S. Geological Survey Open-File Report 88-25, 21 p.

Morgan, J. R., 1968, Structure and stratigraphy of the northern part of the South Virgin Mountains, Clark County, Nevada: M.S. thesis, University of New Mexico, Albuquerque, New Mexico, 102 p.

Narramore, Chester, 1911, Nevada, in Mineral resources of the United States, calendar year 1909, part I-metals: U.S. Geological Survey, p. 380-430.

Narramore, Chester, and Yale, C. G., 1909, Nevada, in Mineral resources of the United States, calendar year 1908, part I-metallic products: U.S. Geological Survey, p. 457-505.

Palache, Charles, Berman, Harry, and Frondel, Clifford, 1944, The system of mineralogy, seventh edition, volume I: John Wiley and Sons, Inc., New York, 834 p.

Pampeyan, E. H., and Bowyer, Ben, 1965, Mineral resources map of Clark County, Nevada, in Longwell, C. R., Pampeyan, E. H., Bowyer, Ben, and Roberts, R. J., Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines Bulletin 62, Plate 1, scale 1:250,000.

Schilling, J. H., 1962, Manganese deposits in Nevada: Nevada Bureau of Mines Map 9, scale 1:1,000,000.

Smith, P. L., and Tingley, J. V., 1983a, A mineral inventory of the Esmeralda-Stateline Resource Area, Las Vegas District, Nevada: Nevada Bureau of Mines and Geology Open-File Report 83-11, 176 p.

______, 1983b, Results of geochemical sampling within Esmeralda-Stateline Resource Area, Esmeralda, Clark, and southern Nye Counties, Nevada (portions of Death Valley, Goldfield, Kingman, Las Vegas, Mariposa and Tonopah 2° sheets): Nevada Bureau of Mines and Geology Open-File Report 83-12, 175 p.

U.S. Bureau of Mines, 1990, Mineral Commodity Summaries: 199 p.

Vanderburg, W. O., 1937, Reconnaissance of mining districts in Clark County, Nevada: U.S. Bureau of Mines Information Circular 6964, 81 p.

Volborth, Alex, 1962, Rapakivi-type granites in the Precambrian complex of Gold Butte, Clark County, Nevada: Geological Society of America Bulletin, v. 73, p. 813-832.

Yale, C. G., 1906, Nevada, in Mineral resources of the United States, calendar year 1905: U.S. Geological Survey, p. 259-275.

_______, 1907, Nevada, in Mineral resources of the United States, calendar year 1906: U.S. Geological Survey, p. 287-300.

_______, 1908, Nevada, in Mineral resources of the United States, calendar year 1907, part I-metallic products: U.S. Geological Survey, p. 337-398.

APPENDIX A

Descriptions and chemical analyses of rock samples from a cobalt/manganese occurrence in the Million Hills study area, Clark County, Nevada

APPENDIX A.--Descriptions and chemical analyses of rock samples from a cobalt/manganese occurrence in the Million Hills study area, Clark County, Nevada

[%, percent; ppm, part per million; ppb, part per billion; NA, not applicable; N, none detected]

Sample				Co	Mn	Au	Ag	Cu	Pb	Zn	Ba	Hg	Ni	Tl
No.	Type	Length (ft)	Description	(ppm)	(%)	(ppb)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppb)	(ppm)	(ppm)
1	Select	NA	Float of manganese-oxide-cemented conglomerate; manganese is massive to dentritic.	1440	1.6	1.5	N	113	290	585	1590	30	313	3.9
2	Chip.	0.6	First of five samples (top to bottom) through section exposed in 20-ft-long trench. This sample through 0.6 ft of semi-consolidated conglomerate with caliche seam along upper and lower contacts.	36	.0445	3.3	N	12	32	40	53	10	18	.65
3	do.	3.0	Consolidated, pink, subangular, sandy conglomerate with pink carbonate matrix; clasts of carbonate and chert range from 1/4 in. to 3 in. in diameter.	6	.0150	1.1	N	7	6	28	25	10	8	.20
4	Select.	NA	Band of black, layered, globular- to botroidal-shaped manganese oxides 0.1 ft thick. Manganese oxides are layered on the ends of the comb structures.	2610	2.3	1.8	N	150	225	1250	1770	15	520	2.8
5	Chip.	3.0	White, massive to banded aragonite with minor calcite occurs as radiating to granular clusters of crystals with minor, fine-grained, silicate sand as contaminant along crystal boundaries.	20	.0285	.6	N	21	7	21	62	15	13	.22
6	Random chip.	NA	Across 0.05-ft-thick zone of banded, beige to pink rock exposed at base of aragonite and manganese-oxide zone.	158	.1950	.7	N	113	25	160	65	30	90	.48

APPENDIX A.--Descriptions and chemical analyses of rock samples from a cobalt/manganese occurrence in the Million Hills study area, Clark County, Nevada--Continued

Sample No.	Type	Length (ft)	Description	Co (ppm)	Mn (%)	Au (ppb)	Ag (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Hg (ppb)	Ni (ppm)	Tl (ppm)
7	Chip.	0.1	Massive, dendritic, and bloom of manganese oxides encrusts hanging wall of open fissure at least 20 ft deep exposed in pit. Fissure strikes N. 27° W. and dips 70° NE.	4120	3.1	0.6	N	333	495	2095	1760	40	1265	8.5
8	Select.	NA	Layered manganese-oxide-rich carbonate rock up to 10 in. thick from dump of small pit.	4935	3.6	1.0	N	343	1205	2030	3100	N	1280	9.2
9	Random chip.	NA	Across 50-ft-long by 20-ft-wide outcrop of massive, black to brown, iron-oxide-encrusted limestone; fresh surface is mottled tan to pink and microcrystalline. Bedding strikes N. 17° E. and dips 45° SE.	15	.0235	.4	N	15	12	24	132	10	6	.19
10	do.	NA	Across 25-ft-wide outcrop of light gray to tan, massive, fossiliferous limestone weathered to medium gray color. Bedding strikes N. 35° E. and dips 42° SE. Limestone cut by 0.5-in.-thick travertine vein and numerous 0.2-in.-thick veins of manganese oxide.	39	.0405	1.7	N	12	40	21	50	15	12	.42
11	Random chip.	NA	Irregular pod of manganese-oxide-cemented conglomerate exposed in 4-ft-diameter pit.	3920	4.0	.6	N	315	1012	1695	2950	N	1150	9.8
12	Chip.	2.0	Zone of massive manganese oxides and aragonite strikes N. 20° E. and dips 45°-70° SE. in conglomerate exposed in 3.2-ft-deep pit. Manganese oxide occurs as matrix and as irregular encrustations.	1880	1.7	1.4	N	122	840	502	1370	20	285	3.7
13	Drill cuttings.	3.0	Hole collared in bottom of pit and drilled into footwall of zone described in sample 12. Cuttings are composed of dark gray manganese oxides, carbonate, and chert.	1760	1.6	1.0	N	143	1015	647	495	10	315	8.2

APPENDIX A.--Descriptions and chemical analyses of rock samples from a cobalt/manganese occurrence in the Million Hills study area, Clark County, Nevada--Continued

Sample														
No.	Type	Length (ft)	Description	Co (ppm)	Mn (%)	Au (ppb)	Ag (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Hg (ppb)	Ni (ppm)	Tl (ppm)
14	do.	2.5	Cuttings of hard, light gray carbonate rock recovered from bottom interval of drill hole.	1030	.9800	1.8	N	94	710	304	840	10	190	5.0
15	Random chip.	NA	Sample of manganese-oxide-rich stringers and pods contained in zone of manganese-oxide-cemented conglomerate which strikes N. 10° E. and dips 55° SE.	1585	2.1	1.1	N	141	1250	495	1850	15	286	12
16	Chip.	1.2	Across zone of aragonite with blebs and stringers of manganeze oxides; zone strikes N. 6° E., and dips 75° SE. in conglomerate.	2210	1.8	1.1	N	192	1015	670	1120	10	369	4.5
17	Chip.	1.2	Same zone as sample 16; manganese oxide occurs as massive replacement, stringers, and dendrites in matrix of conglomerate.	1225	1.6	1.3	N	119	280	990	512	20	368	2.0
18	do.	0.5	Same zone as sample 16; stringers of manganese oxide in conglomerate. A cross-cutting veinlet of manganese oxide strikes N. 65° W. and dips 75° NE.	1905	2.3	1.4	N	152	720	725	1430	105	378	3.4
19	Random chip.	NA	Sample on north side of fault trace across 15 ft of light to dark brown, friable, silty to sandy rock which has been intensely fractured.	20	.1320	1.6	N	36	11	78	562	40	35	.32
20	do.	NA	Sample on south side of fault trace across 30 ft of sheared, intensely argillized and iron-oxide-stained gneiss.	33	.0635	9.2	N	64	30	200	1305	50	80	.46
21	do.	NA	Sample continues south from end of sample 20 across 100 ft of iron-oxide-stained, argillized, friable gneiss.	16	.0660	12	N	136	15	85	950	35	12	.29

APPENDIX B

Chemical analyses of soil samples from a cobalt/manganese occurrence in the Million Hills study area, Clark County, Nevada

APPENDIX B.--Chemical analyses of soil samples from a cobalt/manganese occurrence in the Million Hills study area, Clark County, Nevada

(ppm, part per million; ppb, part per billion; N, none detected)

Transect no.	Station no.(ft)	Co (ppm)	Mn (ppm)	Au (ppb)	Ag (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Hg (ppb)	Ni (ppm)	TL (ppm)
I												
	0	15	385	2.1	N	26	11	63	698	N	36	0.47
	100	20	625	3.2	N	28	13	77	720	10	42	.61
	200	16	475	1.8	N	23	10	60	396	N	31	.47
	300	14	378	1.7	N	20	11	70	315	N	26	.48
	400	6	345	2.5	N	15	7	60	240	20	20	.43
	500	6	496	1.6	N	15	6	54	268	15	18	.42
	550	9	230	1.4	N	16	11	55	140	N	18	.43
	600	42	552	5.2	N	19	40	74	308	N	28	1.00
	650	13	425	3.1	N	17	10	64	340	N	20	.53
	700	14	360	1.9	N	15	9	55	303	N	18	.39
	800	35	705	2.1	N	20	31	74	480	N	28	.88
	900	15	342	1.9	N	20	10	87	288	N	25	.60
	1000	10	402	3.4	.3	20	7	89	153	N	26	.58
	1100	8	365	5.6	N	17	14	60	205	N	19	.47
	1200	13	480	2.2	N	18	11	53	325	N	19	.50
II												
	0	18	665	3.4	N	24	12	66	552	N	32	.43
	100	12	503	4.1	.4	21	8	69	285	10	18	.41
	200	11	395	1.8	.3	18	7	64	245	N	22	.43
	300	9	380	2.6	N	18	6	64	162	N	19	.35
	400	8	418	1.9	N	16	7	55	175	10	16	.39
	450	12	362	2.5	N	16	5	52	253	15	16	.30
	500	18	405	6.2	N	17	12	57	290	25	18	.54
	550	30	516	3.5	N	18	17	61	192	N	23	.64
	600	16	442	2.1	N	18	20	65	225	N	21	.59
	700	23	723	4.2	N	23	45	76	450	10	24	.46
	800	15	430	3.4	.3	20	23	74	412	N	20	.47
	900	18	576	3.7	N	21	20	65	508	N	22	.52
	1000	17	498	4.0	.2	22	9	59	420	10	23	.57

APPENDIX B.--Chemical analyses of soil samples from a cobalt/manganese occurrence in the Million Hills study area, Clark County, Nevada--Continued

Transect no.	Station no.(ft)	Co (ppm)	Mn (ppm)	Au (ppb)	Ag (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Hg (ppb)	Ni (ppm)	Tl (ppm)
III												
	0	10	423	1.8	N	22	8	72	190	N	24	0.31
	100	11	480	1.5	N	22	16	72	376	15	23	.47
	200	11	425	1.4	N	18	25	63	312	15	18	.37
	300	20	620	.8	N	25	17	78	498	10	26	.45
	400	11	365	.7	N	19	20	68	340	N	19	.33
	450	11	320	1.5	N	20	12	59	242	N	20	.38
	500	20	475	1.1	N	19	16	62	302	N	23	.50
	550	25	580	.5	N	20	22	63	382	N	24	.53
	600	18	495	.9	N	19	20	63	475	10	22	.47
	700	16	585	1.2	N	25	11	73	405	N	38	.41
	800	11	460	2.2	N	24	6	85	352	10	33	.43
	900	16	435	2.4	N	27	7	70	415	15	35	.42
	1000	20	610	2.1	N	31	7	73	625	15	39	.46
IV												
	0	30	607	.9	N	18	31	56	182	10	22	.71
	200	10	350	1.2	N	15	4	52	248	10	10	.35
	400	22	627	.8	N	20	17	69	427	N	22	.62
	600	9	475	1.7	N	26	7	93	393	10	32	.50
	800	12	380	2.9	N	28	6	63	203	10	30	.46
	1000	18	615	1.3	N	26	7	66	585	10	37	.50
	1200	16	910	.9	N	29	8	73	675	N	38	.54
	1400	16	755	2.7	N	29	7	68	570	15	39	.43
	1600	15	718	1.8	N	30	8	69	648	15	39	.47
	1800	16	944	1.1	N	32	9	79	745	N	46	.46
	2000	24	980	1.0	N	36	9	97	655	N	56	.44
	2200	17	1050	2.8	N	34	10	82	805	N	51	.54
	2400	17	675	4.5	N	28	8	63	535	10	37	.50
	2600	16	590	7.6	N	27	5	60	514	10	35	.48
	2800	16	815	3.2	N	29	7	70	565	N	39	.49
	3000	21	760	4.0	N	34	6	74	708	N	44	.50
	3200	15	585	4.1	N	32	9	69	572	10	37	.52
	3400	18	680	4.2	N	32	9	67	585	15	42	.46

APPENDIX B.--Chemical analyses of soil samples from a cobalt/manganese occurrence in the Million Hills study area, Clark County, Nevada--Continued

Transect no.	Station no. (ft)	Co (ppm)	Mn (ppm)	Au (ppb)	Ag (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Hg (ppb)	Ni (ppm)	Tl (ppm)
	3600	19	825	2.7	N	42	8	76	705	N	52	0.42
	3800	18	755	3.6	N	40	8	75	645	N	47	.52
	4000	17	742	3.8	N	34	10	71	612	N	45	.46
	4200	16	737	4.2	N	37	10	76	760	10	42	.58
	4400	20	765	2.3	N	40	11	78	728	10	48	.65

APPENDIX C

Geophysical data from a cobalt/manganese occurrence in the Million Hills study area, Clark County, Nevada

APPENDIX C.--Geophysical data from a cobalt/manganese occurrence in the Million Hills study area, Clark County, Nevada

[cps, count per second; %, percent]

Transect no.	Station no. (ft)	Radiometric (cps)	Magnetic (gammas)	VLF Electromagnetic In-phase (%)	VLF Electromagnetic Quadature (%)
I					
	0	25	51530	-58	-12
	100	23	51488	-56	-18
	200	20	51345	-58	-30
	300	16	51370	-60	-20
	400	12	51397	-54	-12
	500	12	51353	-56	4
	550	10	51352	-29	0
	600	12	51380	10	16
	650	11	51388	-14	4
	700	11	51427	-11	14
	800	12	51358	-31	12
	900	16	51372	-31	-14
	1000	16	51392	-58	-8
	1100	15	51360	-24	14
	1200	15	51330	-58	-22
II					
	0	24	51320	-60	34
	100	19	51320	-60	34
	200	15	51308	-60	10
	300	12	51300	-56	-6
	400	11	51350	-31	-28
	450	10	51343	-22	-34
	500	11	51358	-14	-36
	550	11	51353	-10	-32
	600	9	51340	-3	-36
	700	11	51367	-45	-32
	800	13	51340	60	-12
	900	15	51320	60	-26
	1000	17	51313	56	-30
III					
	0	16	51368	-3	20
	100	14	51398	-14	20
	200	12	51438	-27	34
	300	18	51383	-42	14
	400	14	51373	-27	-16
	450	12	51338	-3	-38
	500	11	51340	8	-30
	550	16	51370	11	-26

APPENDIX C.--Geophysical data from a cobalt/manganese occurrence in the Million Hills study area, Clark County, Nevada--Continued

Transect no.	Station no. (ft)	Radiometric (cps)	Magnetic (gammas)	VLF Electromagnetic In-phase (%)	VLF Electromagnetic Quadature (%)
III--Continued					
	600	16	51357	18	-28
	700	24	51380	31	-21
	800	24	51368	56	-10
	900	24	51337	39	-20
	1000	24	51363	6	0
IV					
	0	10	51365	-6	10
	200	12	51375	-56	-38
	400	14	51365	-60	-42
	600	22	51330	-60	-40
	800	23	51400	-60	-36
	1000	28	51375	-60	-34
	1200	28	51360	-17	10
	1400	25	51400	-29	-36
	1600	26	51370	-22	-10
	1800	23	51370	-9	-30
	2000	23	51310	-14	-14
	2200	24	51370	-17	-20
	2400	24	51365	-19	-10
	2600	24	51240	-11	-32
	2800	24	51340	-6	14
	3000	23	51360	-14	-22
	3200	27	51270	6	-22
	3400	25	51405	9	38
	3600	22	51255	19	22
	3800	25	51110	-6	22
	4000	25	51210	-17	-10
	4200	22	51300	58	0
	4400	23	51340	24	-30

APPENDIX D

Petrographic analyses of rock specimens from a cobalt/manganese occurrence in the Million Hills study area, Clark County, Nevada

PETROGRAPHIC ANALYSES OF ROCK SPECIMENS

Petrographic Analysis of Sample WS-1309 by Transmitted Light

Two-thirds of sample WS-1309 (fig. D-1) is a sandy conglomerate (intrasparrudite) composed of large clasts of carbonate and chert. One-third of the rock is composed of dendritic(?) manganese opaques and sparry aragonite. The silt- and sand-sized grains in the conglomerate matrix are quartz, potassium feldspar, chert, muscovite, biotite (stilpnomelane?), tourmaline, and zircon in a matrix of carbonate. The pebbles are mostly intraclasts of clastic micrite, which appears fossiliferous or at least pelletal, and dolomite. One pebble is chert and another is dolomitic chert. The finer matrix is sandy micrite and sparry carbonate (mostly aragonite). The large carbonate clasts are rectangular, rounded, and contain fragments which look like partial chambers from gastropods(?), and other fibrous fragments appear to be parts of pelecypod shells. Spheroids are also present within some clasts and may represent either fecal pellets or recrystallized oolites. The largest clast is approximately one centimeter long.

The contact between the coarse clastic carbonate portion of the rock and the manganese-carbonate portion is marked by a coarse comb-structured aragonite, 0.3 mm across, capped by a thin layer (0.01 mm) of manganese opaques (fig. D-2). This feature is also found in sample WS-1310, but the aragonite is finer grained (0.05 mm) in WS-1310. This indicates open-space filling for at least the manganese opaque layer and underlying aragonite combs. The manganese opaque/aragonite portion of the rock is characterized by coarse (0.05 to 1.8 mm) sparry aragonite and globular to elongate rounded masses of manganese opaques. Some of the opaques are branching and globular and are similar in gross design to some forms of staghorn coral (this is for comparison only - no relationship to coral is intended). The rounded manganese masses have interlayered crescent-shaped lenses of sparry aragonite. It has the appearance of colloidal deposition. The sparry aragonite in the manganese-rich portion of the rock contains abundant fluid inclusions. The concentration of these inclusions is highest adjacent to the manganese opaques and grades to nearly zero midway between the opaques. A sparry aragonite veinlet in the clastic portion of the rock also contains fluid inclusions, but their concentration is irregular and not obviously related to any segment of the sample.

James R. Snook
Certified Professional Geologist 1718

FIGURE D-1.--Cobalt/manganese-bearing rock specimens on which petrographic analyses were conducted

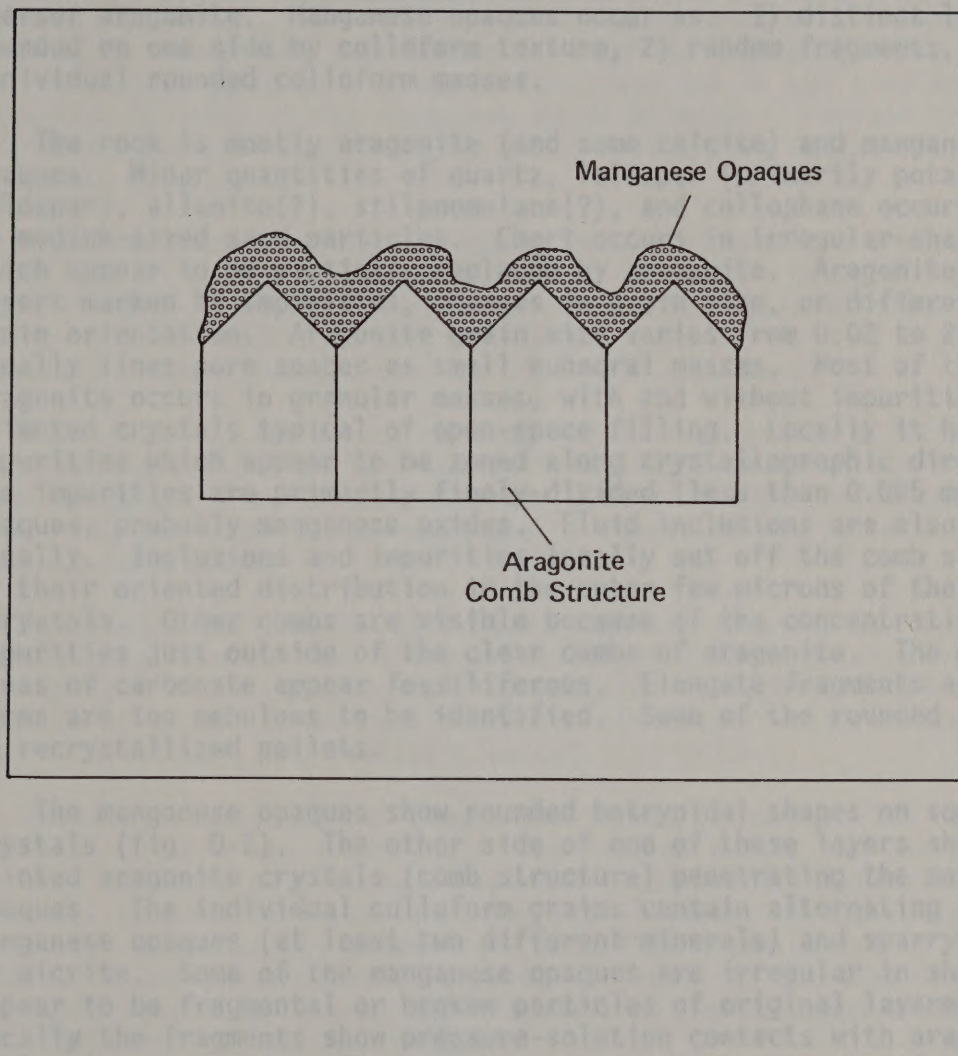


FIGURE D-2.—Illustration shows botryoidal-shaped manganese opaques on comb-structured aragonite

Petrographic Analysis of Sample WS-1310 by Transmitted Light

Sample WS-1310 (fig. D-1) contains early fragments of sandy micrite which are partially replaced by sparry calcite and aragonite. Some of the sparry carbonate is calcite (shows rhombohedral cleavage) and some is aragonite (shows biaxial figure). Micrite is also present in irregular-shaped areas throughout the rock and appears to be replaced by coarser aragonite. Manganese opaques occur as: 1) distinct layers bounded on one side by colloform texture, 2) random fragments, and 3) individual rounded colloform masses.

The rock is mostly aragonite (and some calcite) and manganese opaques. Minor quantities of quartz, feldspar (primarily potassium feldspar), allanite(?), stilpnomelane(?), and collophane occur as fine- to medium-sized sand particles. Chert occurs in irregular-shaped masses which appear to be partially replaced by aragonite. Aragonite occurs in layers marked by impurities, changes in grain size, or differences in grain orientation. Aragonite grain size varies from 0.02 to 2.0 mm. It locally lines pore spaces as small euhedral masses. Most of the aragonite occurs in granular masses, with and without impurities, and oriented crystals typical of open-space filling. Locally it has impurities which appear to be zoned along crystallographic directions. The impurities are primarily finely-divided (less than 0.005 mm) opaques, probably manganese oxides. Fluid inclusions are also present locally. Inclusions and impurities locally set off the comb structure by their oriented distribution in the outer few microns of the aragonite crystals. Other combs are visible because of the concentration of impurities just outside of the clear combs of aragonite. The micritic areas of carbonate appear fossiliferous. Elongate fragments and rounded forms are too nebulous to be identified. Some of the rounded forms may be recrystallized pellets.

The manganese opaques show rounded botryoidal shapes on some crystals (fig. D-2). The other side of one of these layers shows pointed aragonite crystals (comb structure) penetrating the manganese opaques. The individual colloform grains contain alternating layers of manganese opaques (at least two different minerals) and sparry aragonite or micrite. Some of the manganese opaques are irregular in shape and appear to be fragmental or broken particles of original layered opaques. Locally the fragments show pressure-solution contacts with aragonite, at least on one side. The manganese opaque textures are primarily those associated with open-space filling and colloidal deposition (globular forms). The fragmental textures appear post depositional and have been partially replaced by aragonite. The aragonite is all secondary and locally has replaced micrite, chert, sand grains, and manganese opaques.

James R. Snook
Certified Professional Geologist 1718

Petrographic Analysis of Sample KS-1310 by Transmitted Light

Sample KS 1310 (Fig. D-1) contains early fragments of sandy micrite which are partially replaced by sparry calcite and aragonite. Some of the sparry carbonate is calcite (shows rhombohedral cleavage) and some is aragonite (shows biaxial figure). Micrite is also present in irregular-shaped areas throughout the rock and appears to be replaced by coarser aragonite. Manganese opaques occur as: 1) distinct layers bounded on one side by colloform texture, 2) random fragments, and 3) individual rounded colloform masses.

The rock is mostly aragonite (and some calcite) and manganese opaques. Minor quantities of quartz, feldspar (primarily potassium feldspar), allanite(?), stilpnomelane(?), and collophane occur as fine- to medium-sized sand particles. Chert occurs in irregular-shaped masses which appear to be partially replaced by aragonite. Aragonite occurs in layers marked by impurities, changes in grain size, or differences in grain orientation. Aragonite grain size varies from 0.02 to 2.0 mm. It locally lines pore spaces as small euhedral masses. Most of the aragonite occurs in granular masses, with and without impurities, and oriented crystals typical of open-space filling. Locally it has impurities which appear to be zoned along crystallographic directions. The impurities are primarily finely-divided (less than 0.005 mm) opaques, probably manganese oxides. Fluid inclusions are also present locally. Inclusions and impurities locally set off the comb structure by their oriented distribution in the outer few microns of the aragonite crystals. Other combs are visible because of the concentration of impurities just outside of the clear combs of aragonite. The micritic areas of carbonate appear fossiliferous. Elongate fragments and rounded forms are too nebulous to be identified. Some of the rounded forms may be recrystallized pellets.

The manganese opaques show rounded botryoidal shapes on some crystals (Fig. D-2). The other side of one of these layers shows pointed aragonite crystals (comb structure) penetrating the manganese opaques. The individual colloform grains contain alternating layers of manganese opaques (at least two different minerals) and sparry aragonite or micrite. Some of the manganese opaques are irregular in shape and appear to be fragmental or broken particles of original layered opaques. Locally the fragments show pressure-solution contacts with aragonite, at least on one side. The manganese opaque textures are primarily those associated with open-space filling and colloidal deposition (globular forms). The fragmental textures appear post depositional and have been partially replaced by aragonite. The aragonite is all secondary and locally has replaced micrite, chert, sand grains, and manganese opaques.

James R. Snook
Certified Professional Geologist 1718

Petrographic Analysis of Sample WS-1310 by Reflected Light

The opaque manganese minerals in sample WS-1310 consist of at least three different minerals. They occur as colloform layers with each layer consisting of one or more manganese minerals. The two most common minerals, which occur in about equal amounts, are asbolane, $(Co,Ni)_{1-y}(MnO_2)_{2-x}(OH)(OH)_{2-2y-x}nH_2O$, and either pyrolusite, $(MnO)_2$, or ramsdellite, $(MnO)_2$. The third mineral, which occurs in somewhat lesser amounts, is romanchite (psilomelane), $BaMn^{2+}Mn^{4+}{}_8O_{16}(OH)_4$. These identifications must be considered tentative due to the similar optical properties of many of the manganese oxide minerals. Further verification would require either X-ray diffraction and/or electron microprobe examination.

Asbolane occurs as fibrous masses generally oriented approximately perpendicular to the colloform layering. It is characterized by its pinkish brown color and pleochroism, low reflectance, moderate to strong anisotropy, and pinkish brown anisotropic colors. In most cases romanchite occurs interstitial to the asbolane fibers.

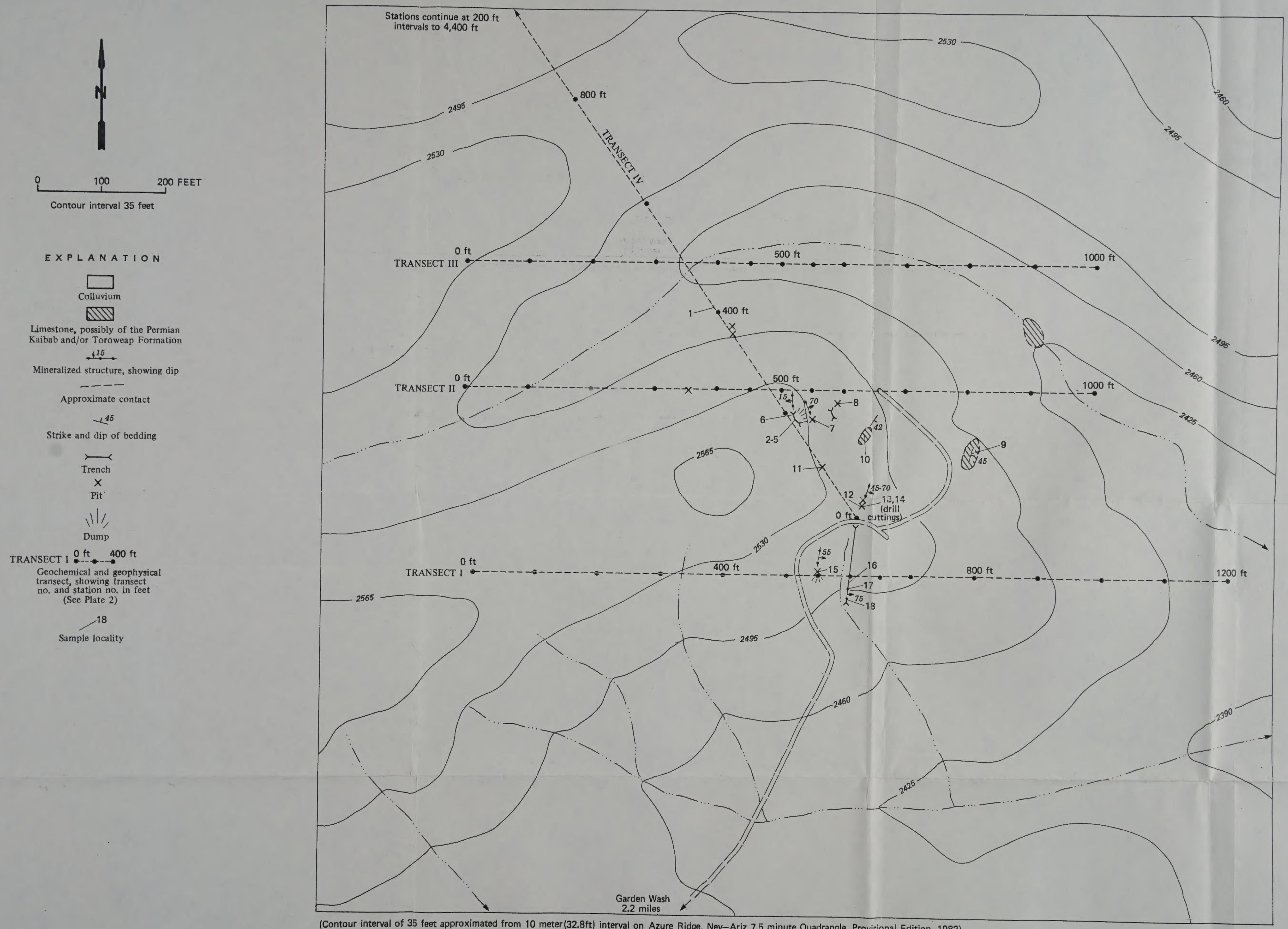
Romanchite occurs as separate colloform layers with a radial fibrous to cryptocrystalline texture and as interstitial material in the asbolane layers. It is characterized by its moderate reflectance, white color, fibrous texture, and moderate to strong anisotropy with no distinct coloration.

Pyrolusite (or ramsdellite) occurs as fine granular to cryptocrystalline colloform layers, intergrown in some cases with romanchite. It is characterized by moderate reflectance, white color, moderate to strong anisotropy (although not readily observed due to the small grain size), and yellowish anisotropic colors.

Manganese oxide mineral layers are interlayered with the carbonate minerals (calcite and aragonite). The layered nature and the colloform textures indicate open-space deposition either from solution or a colloidal suspension (with later recrystallization of the colloidal gel). The textures and presence of aragonite would generally indicate a relatively low temperature of deposition. Some of the layering has been disrupted to a minor extent and fragments of the manganese oxide layers redeposited in the carbonate layers.

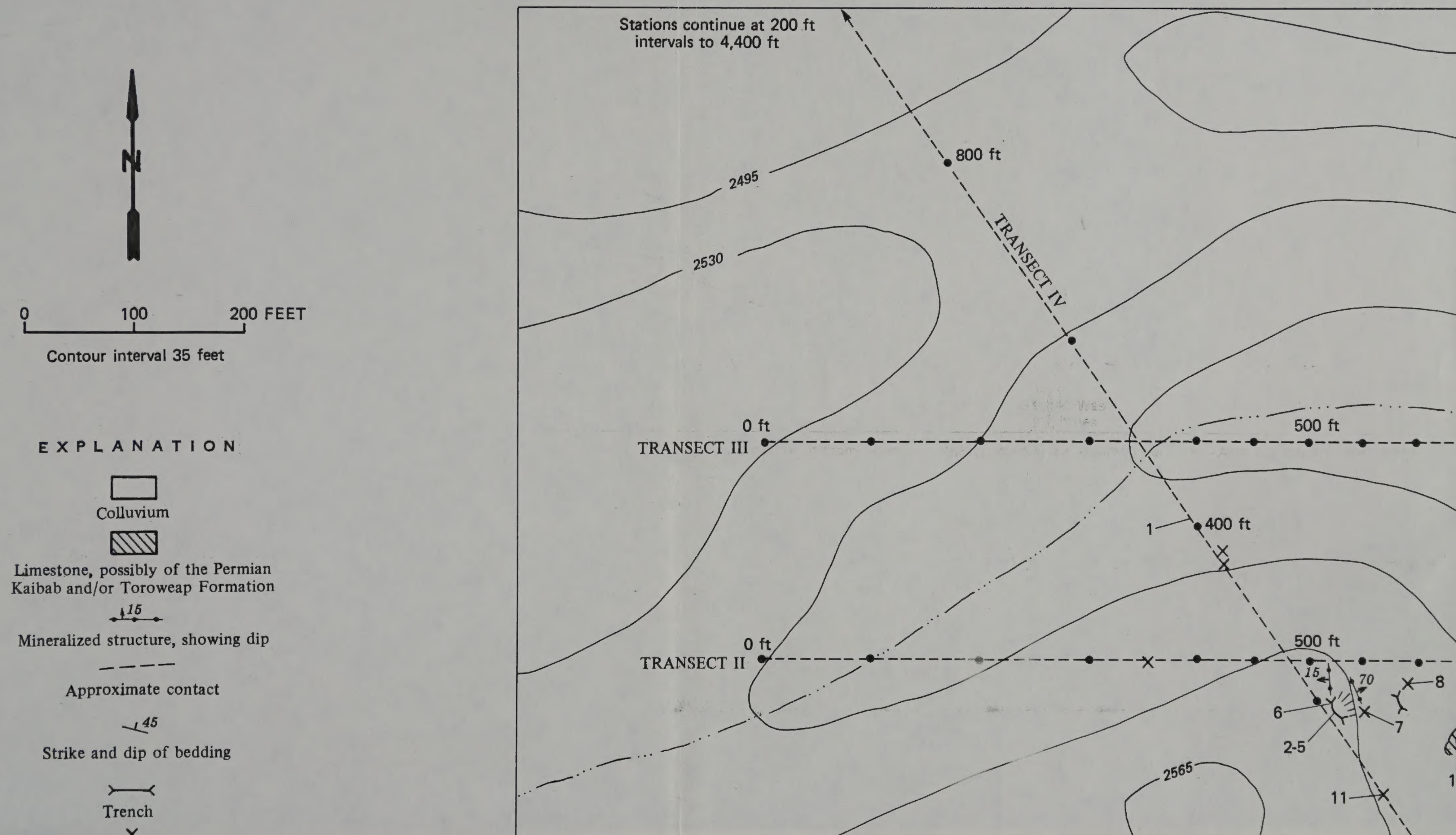
Russell Boggs
Associate Professor of Geology

U.S. BUREAU OF MINES
Open-File Report MLA 3-90, Plate 1

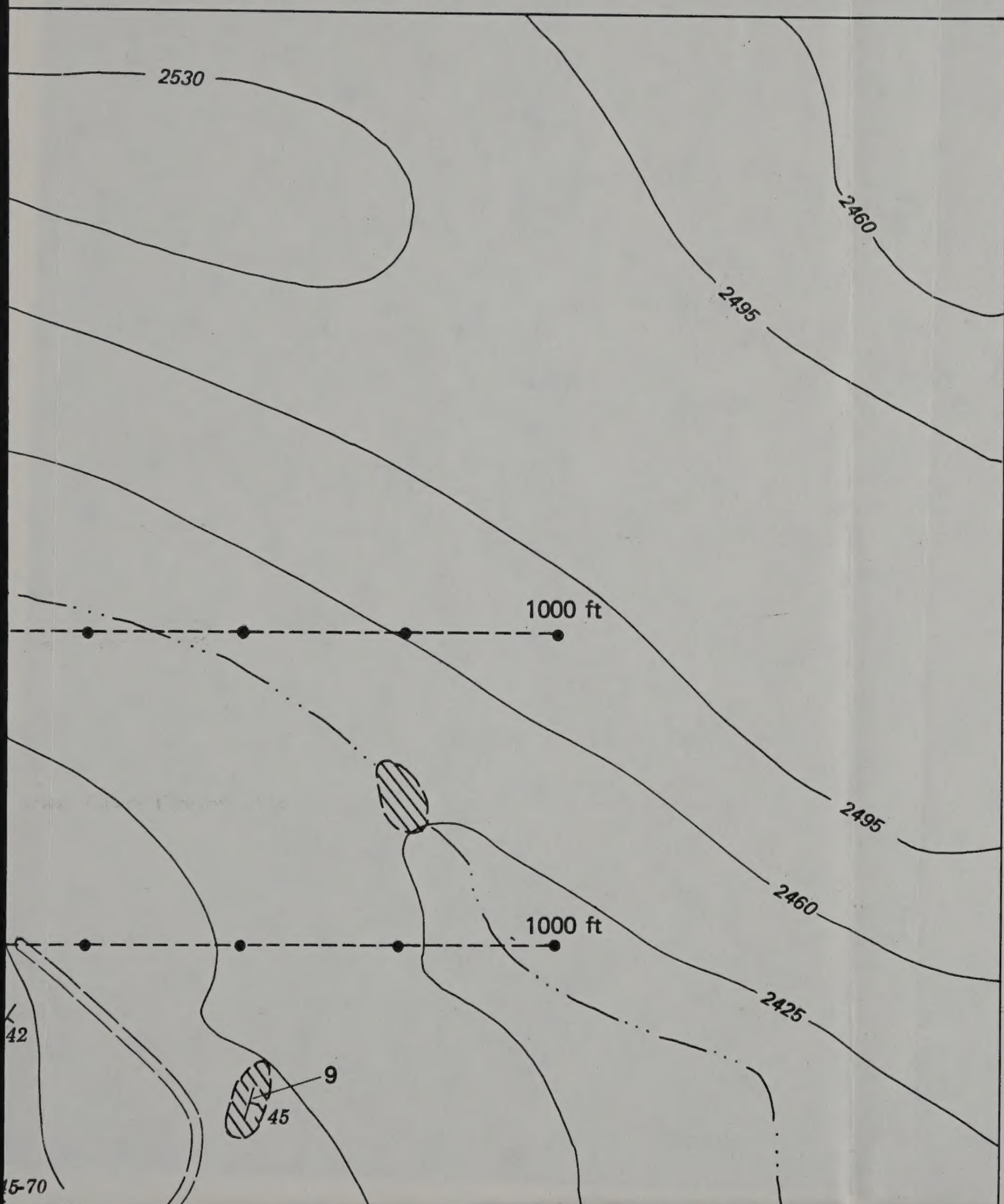


(Contour interval of 35 feet approximated from 10 meter (32.8ft) interval on Azure Ridge, Nev–Ariz 7.5 minute Quadrangle, Provisional Edition, 1983)

PLATE 1.-Workings, sample localities, and sample transects at a cobalt/manganese occurrence in the Million Hills study area, Clark County, Nevada


N
0
100
200 FEET
Contour interval 35 feet
EXPLANATION
Colluvium
Limestone, possibly of the Permian Kaibab and/or Toroweap Formation
15
Mineralized structure, showing dip
Approximate contact
45
Strike and dip of bedding
Trench
Stations continue at 200 ft intervals to 4,400 ft
800 ft
TRANSECT IV
2495
2530
0 ft
TRANSECT III
500 ft
1
400 ft
0 ft
TRANSECT II
500 ft
15
70
8
6
7
2-5
2565
10
11
12

U.S. BUREAU OF MINES
Open-File Report MLA 3-90, Plate 1



Pit

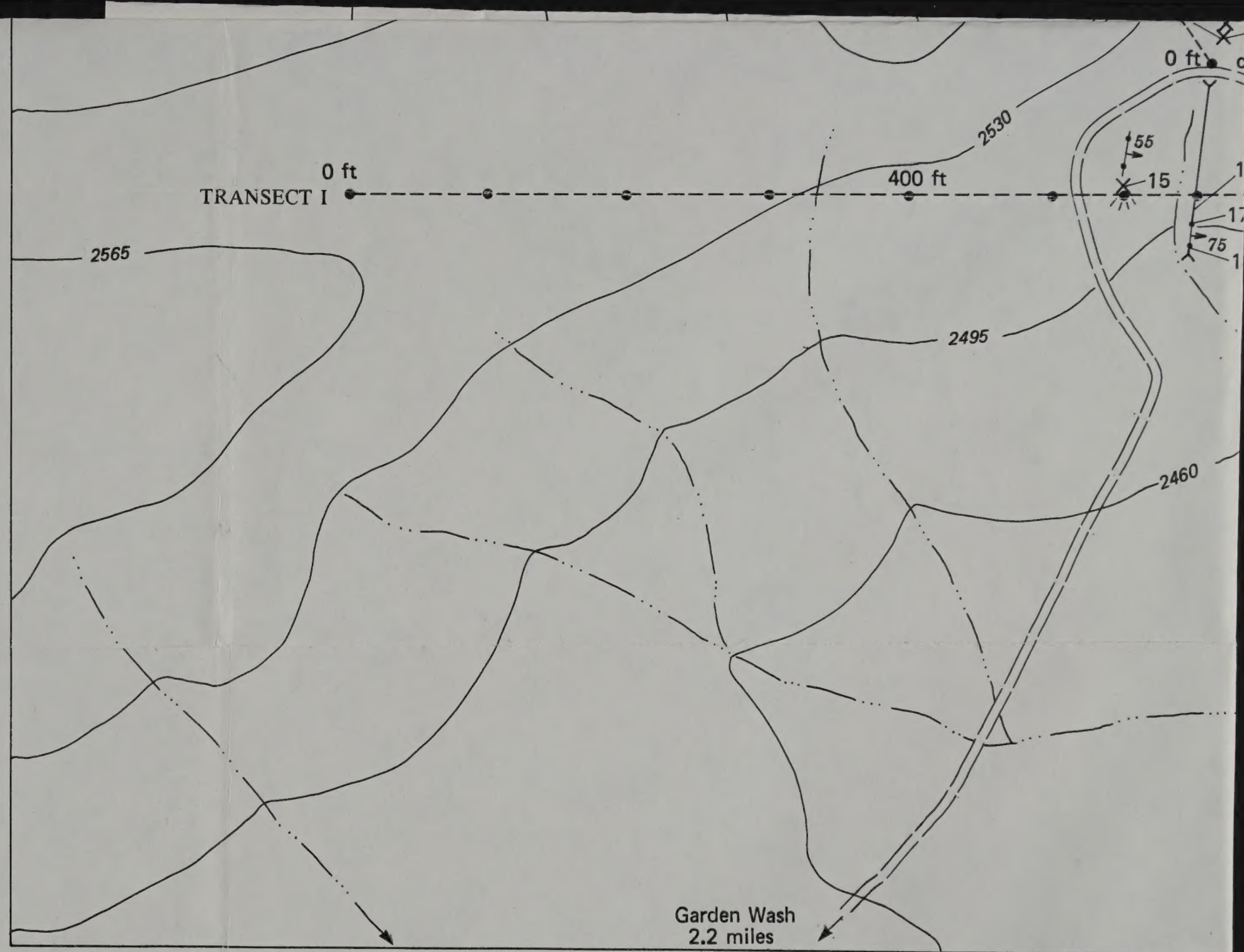
Dump

TRANSECT I 0 ft 400 ft

Geochemical and geophysical transect, showing transect no. and station no. in feet (See Plate 2)

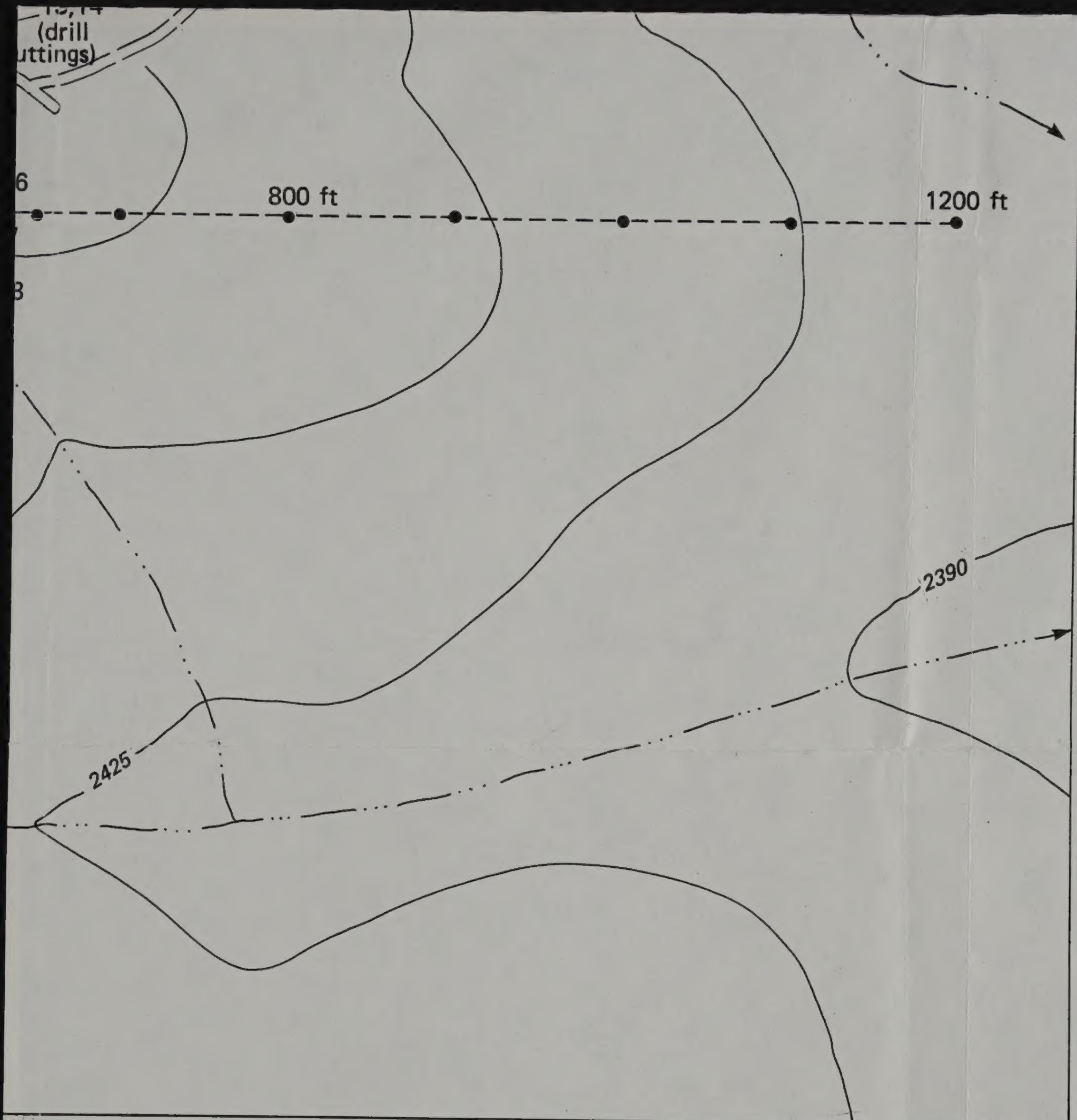
18

Sample locality



(Contour interval of 35 feet approximated from 10 meter(32.8ft) interval on Azure Ridge, Nev–Ariz 7.5 minute Quadrangle, Pro

PLATE 1.-Workings, sample localities, and sample transects at a cobalt/manganese occurrence in the Million Hills stu



visional Edition, 1983)

dy area, Clark County, Nevada

U.S. BUREAU OF MINES
Open-File Report MLA 3-90, Plate 2

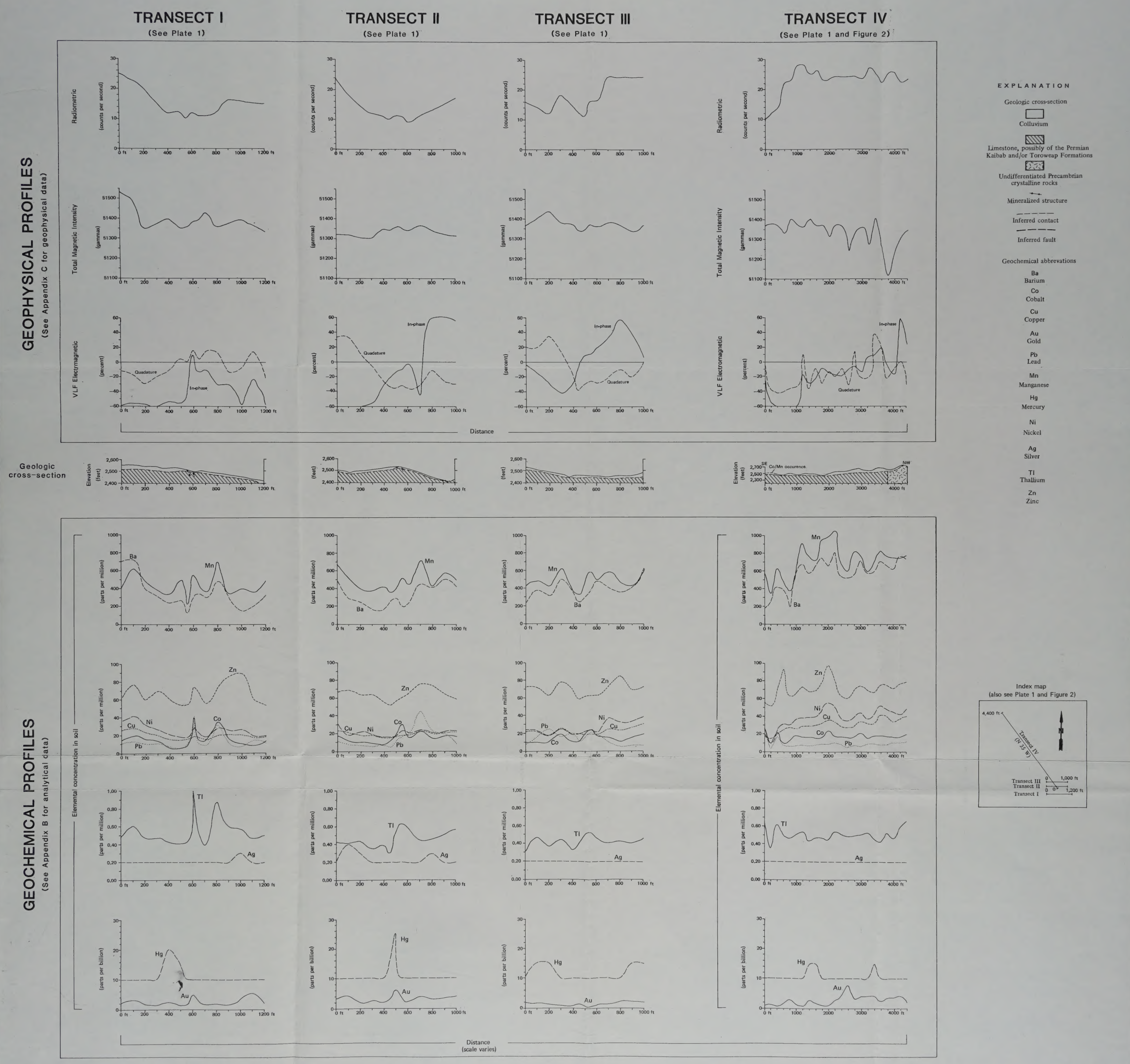
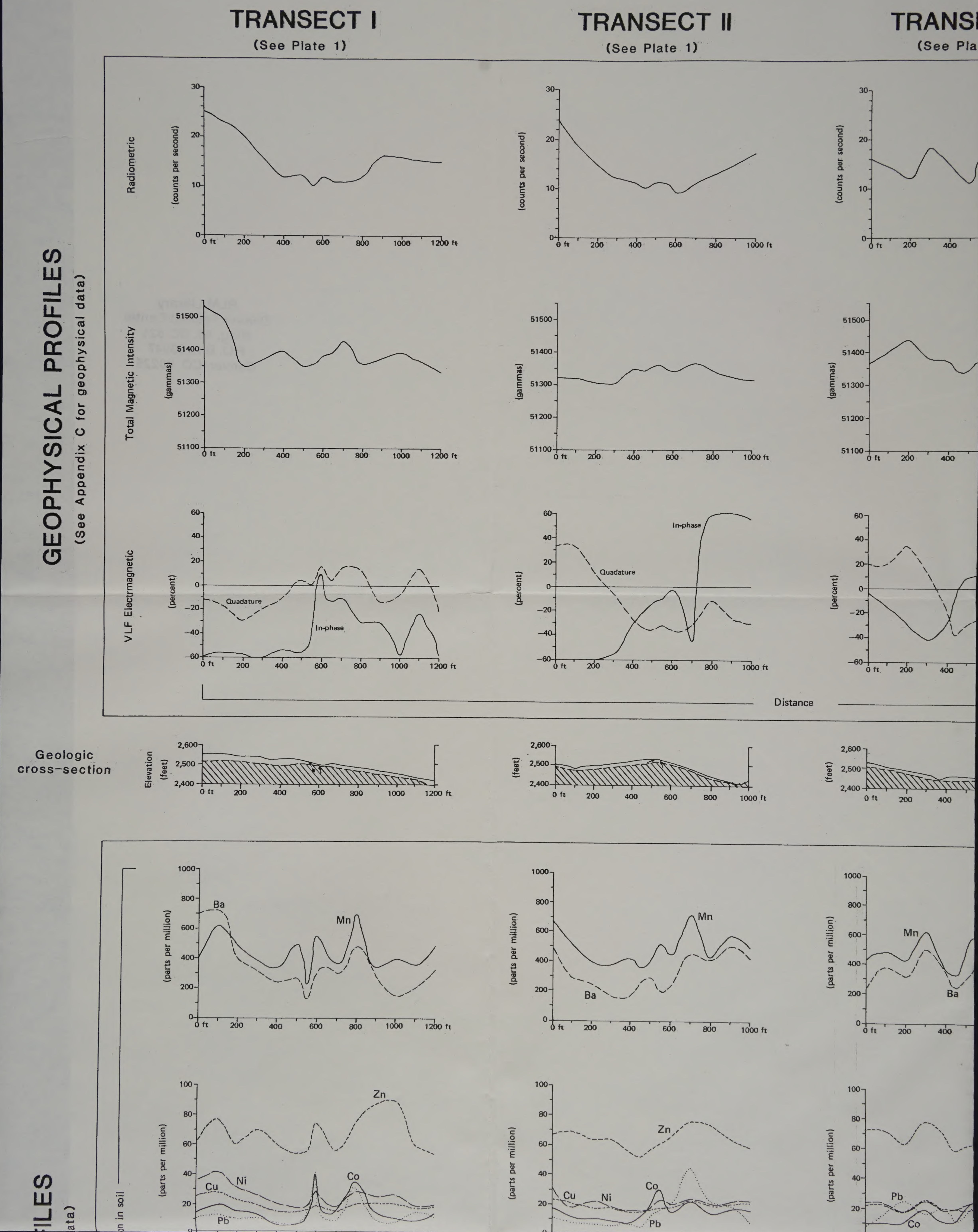


PLATE 2.- Geochemical and geophysical profiles along transects at a cobalt/manganese occurrence in the Million Hills study area, Clark County, Nevada

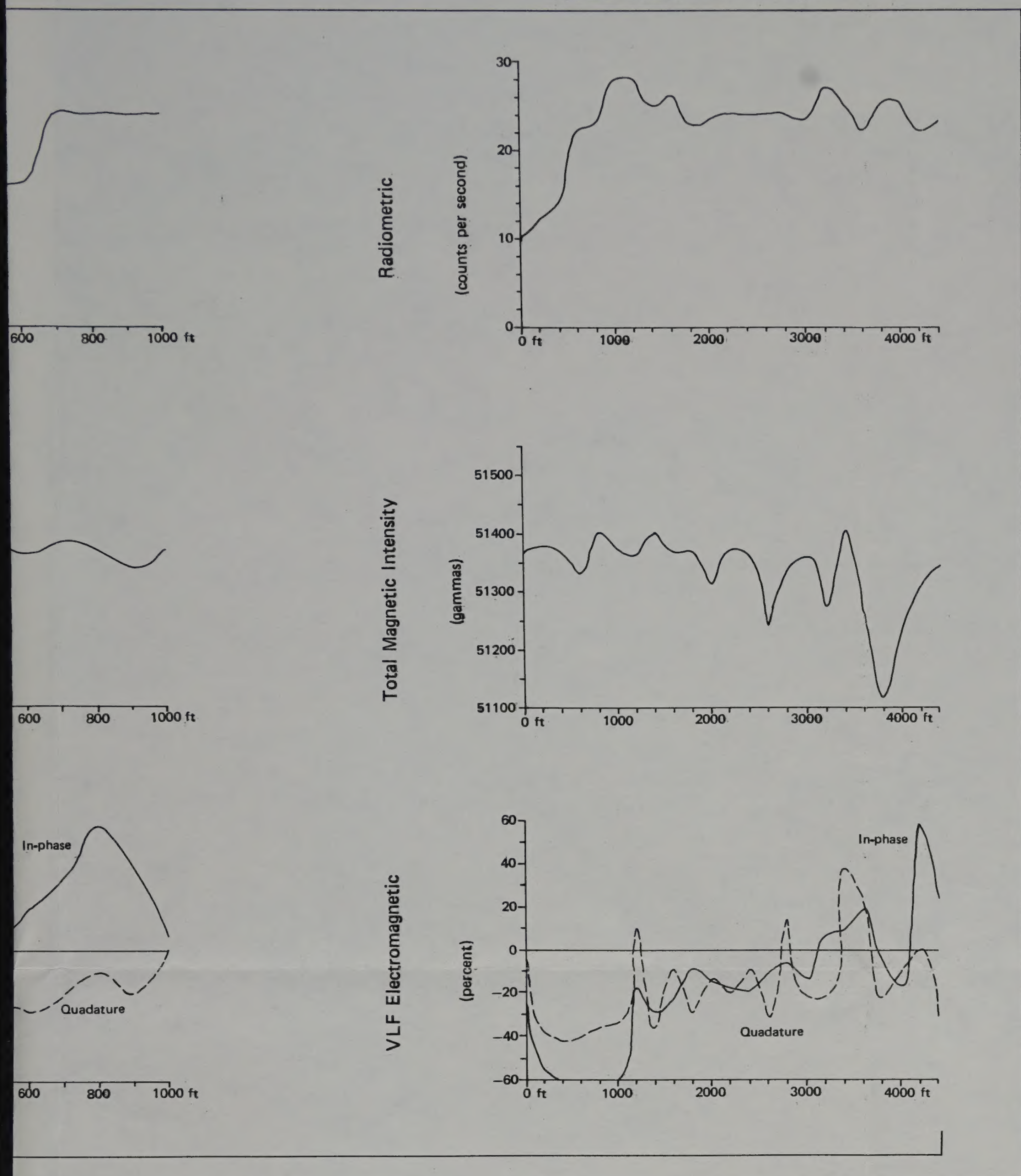

TRANSECT I
(See Plate 1)
TRANSECT II
(See Plate 1)
TRANSE
(See Plat
GEOPHYSICAL PROFILES
(See Appendix C for geophysical data)
Radiometric
(counts per second)
Total Magnetic Intensity
(gammas)
VLF Electrmagnetic
(percent)
Quadature
In-phase
Distance
Geologic cross-section
Elevation (feet)
(parts per million)
Ba
Mn
Zn
Cu
Ni
Co
Pb
ILES
ata)
on in soil

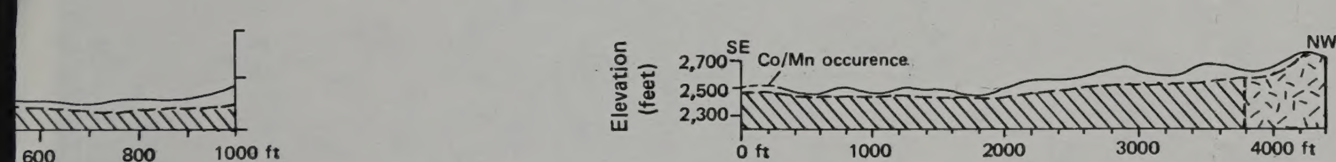
ECT III

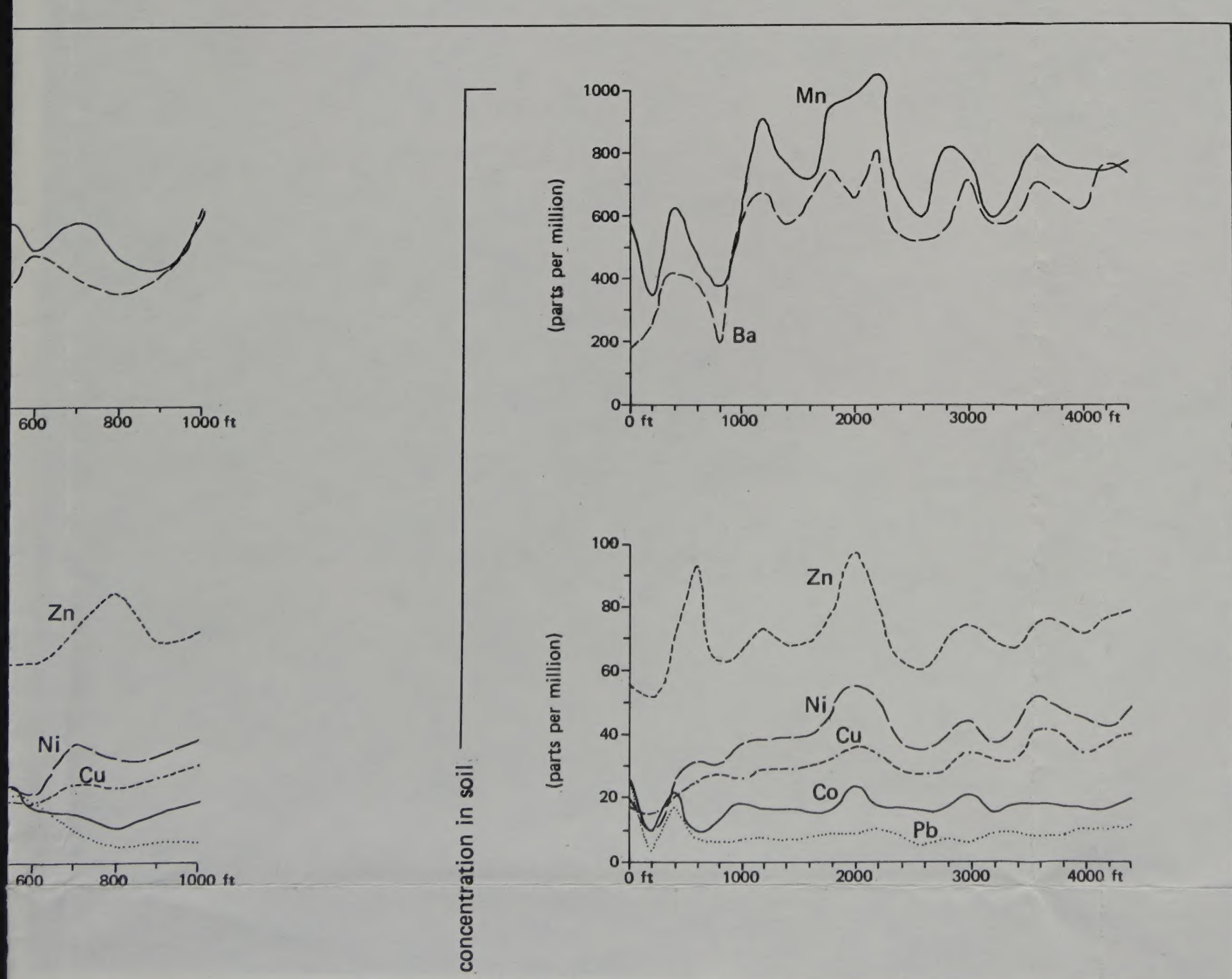
e 1)

TRANSECT IV

(See Plate 1 and Figure 2)







EXPLANATION

Geologic cross-section

Colluvium

Limestone, possibly of the Permian Kaibab and/or Toroweap Formations

Undifferentiated Precambrian crystalline rocks

Mineralized structure

Inferred contact

Inferred fault

Geochemical abbrevations

Ba
Barium

Co
Cobalt

Cu
Copper

Au
Gold

Pb
Lead

Mn
Manganese

Hg
Mercury

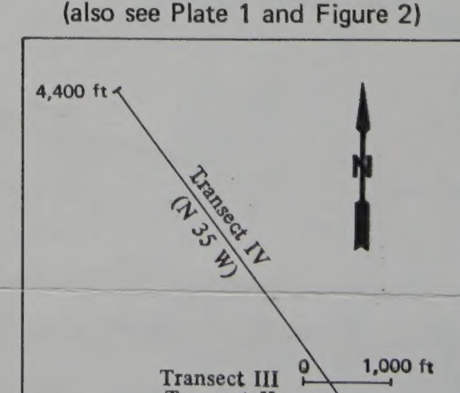
Ni
Nickel

Ag
Silver

Tl
Thallium

Zn
Zinc

Index map
(also see Plate 1 and Figure 2)



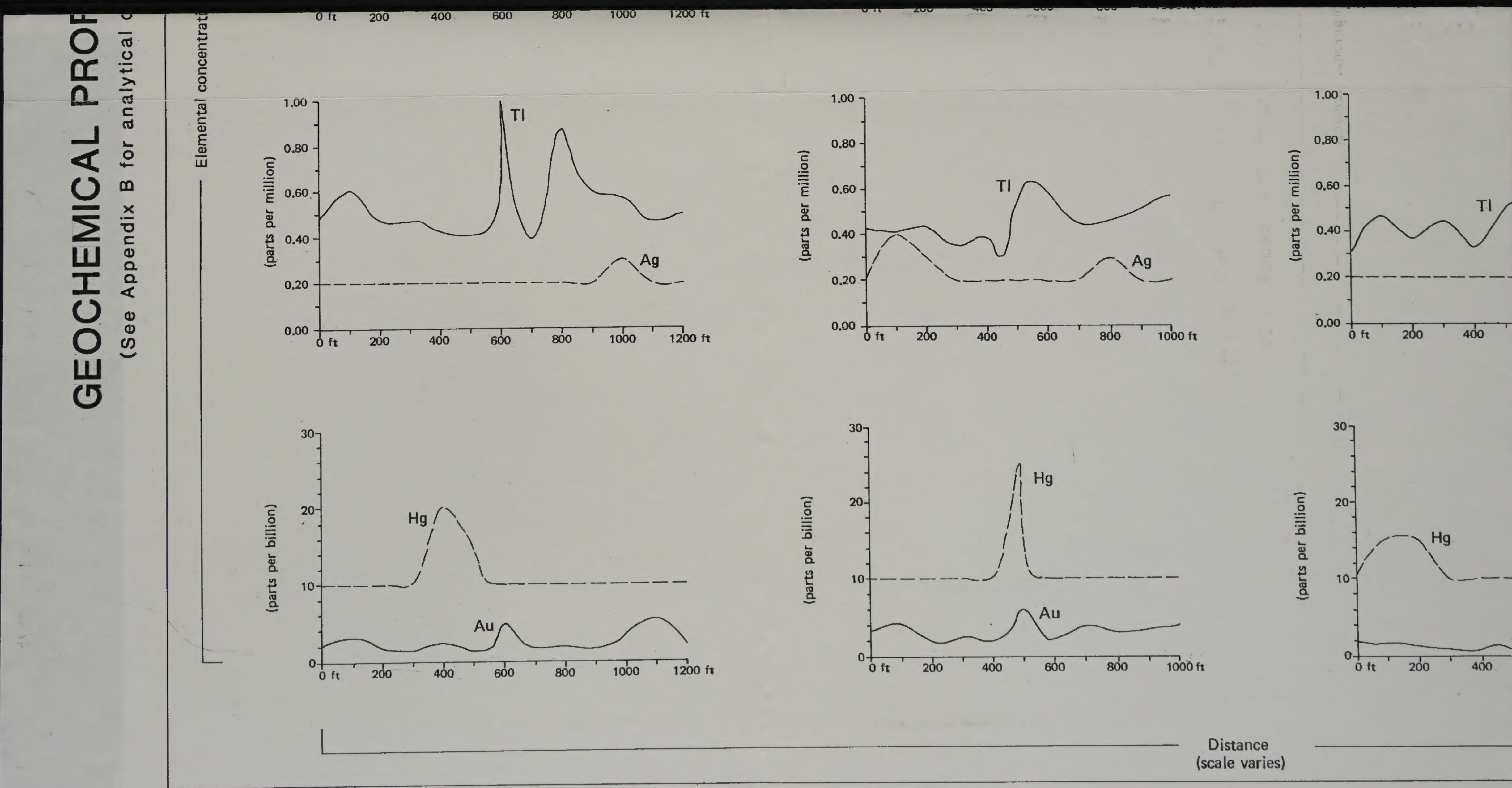
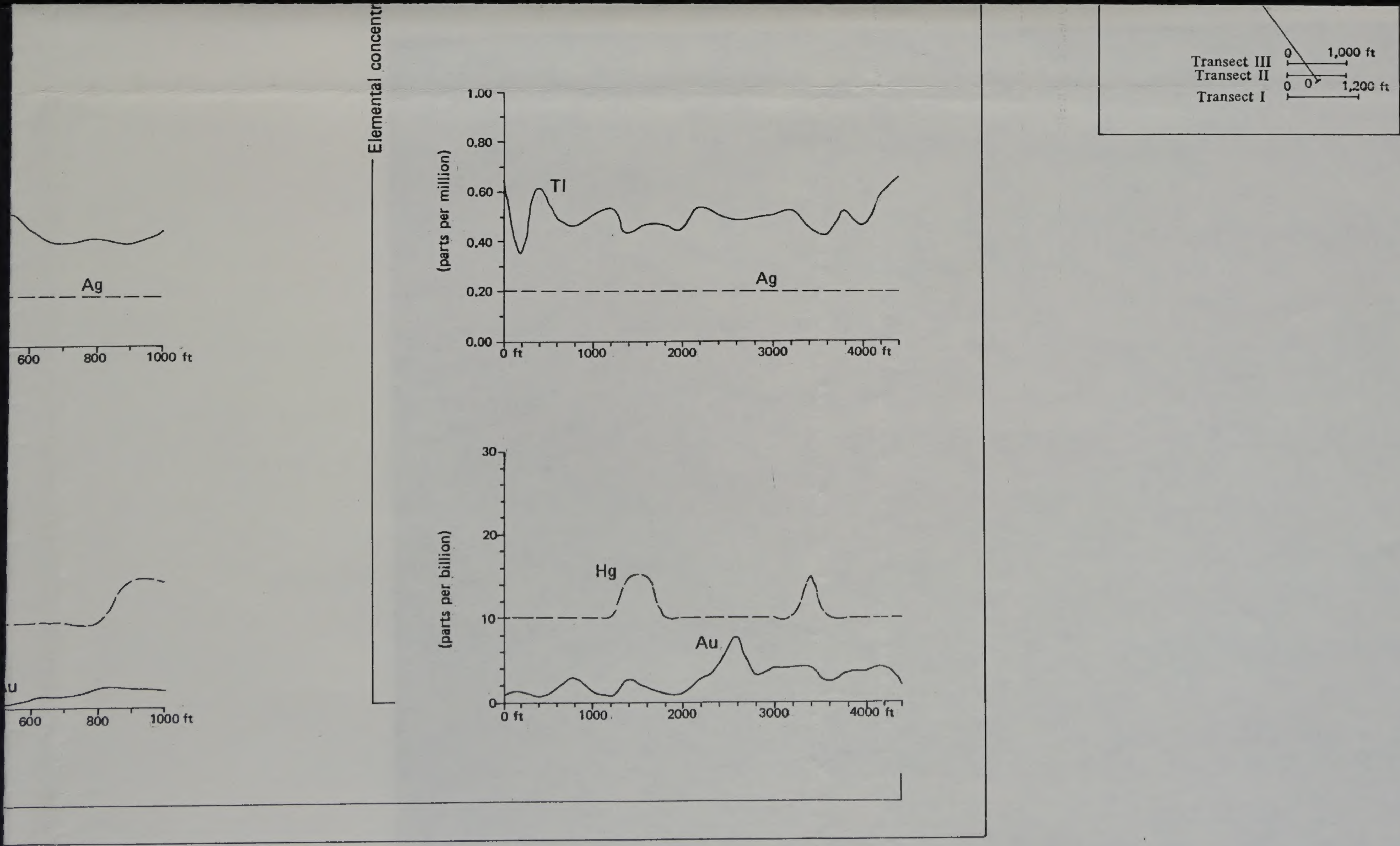
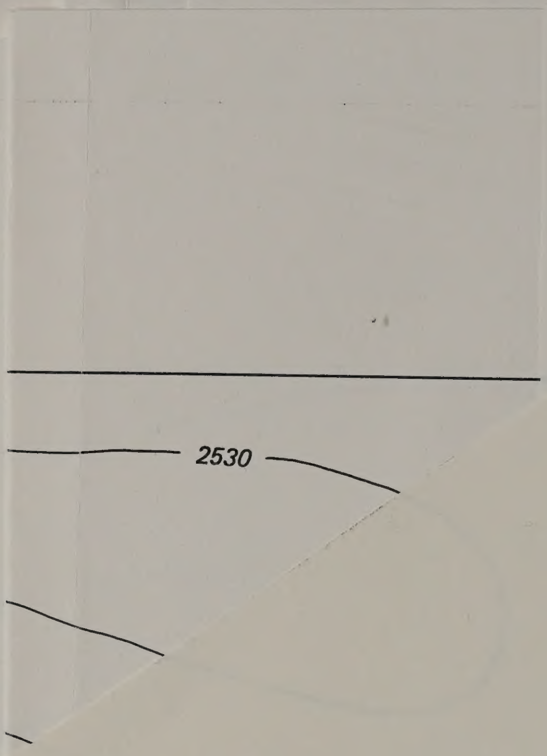


PLATE 2.- Geochemical and geophysical profiles along transects at a cobalt/manganese occurr



ence in the Million Hills study area, Clark County, Nevada


2530